UTILIZING LACTIPRO (*MEGASPHAERA ELSDENII* NCIMB 41125) TO ACCELERATE ADAPTATION OF CATTLE TO HIGH-CONCENTRATE DIETS AND IMPROVE THE HEALTH OF HIGH-RISK CALVES.

by

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B.S., KANSAS STATE UNIVERSITY, 2006

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AN ABSTRACT OF A DISSERTATION

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Abstract

Four experiments were conducted to evaluate the potential for accelerating adaption to high-concentrate diets and improving the health of high-risk calves, by administering an oral dose of *Megasphaera elsdenii*. Lactipro, a probiotic containing a live culture of *Megasphaera elsdenii* (10^9 CFU/mL), was orally dosed to cattle (100 mL) at initial processing. In experiment 1, heifers were adapted to a high-concentrate diet in 21 d without Lactipro or dosed with Lactipro and adapted in 16 d, 11 d, 6 d, or fed the high-concentrate diet d 1. Accelerating adaptation decreased DMI (P = 0.09), ADG, and efficiency (P < 0.05) during the first 30 d compared to cattle adapted over 21 d. Over 129 d, DMI and ADG were not different ($P \geq 0.12$), but efficiency tended (P = 0.08) to be better for cattle adapted over 21 d. Liver abscesses and carcass traits were not different between treatments, with the exceptions of LM area (quadratic, P < 0.01) and marbling (linear, P = 0.07), which tended to increase with accelerated adaptation protocols. In experiment 2, cattle dosed with Lactipro and placed directly onto the finishing diet required less roughage (P < 0.01), tended to have lower DMI (P = 0.07), better quality grade ($P \leq 0.07$), and similar ADG and efficiency ($P \geq 0.14$) compared to cattle adapted over 18 d without Lactipro. Over the first 24 d DMI, DM fecal output, and apparent total tract NDF digestibility were greater (P < 0.01) for cattle adapted over 18 d. In Experiment 3, dosing calves, of Mexican origin, with Lactipro did not affect performance ($P \geq 0.16$). Second antibiotic therapies for undifferentiated bovine respiratory disease (UBRD) tended (P = 0.06) to be lower in calves dosed Lactipro. In Experiment 4, dosing calves from Texas with Lactipro increased DMI, ADG, and efficiency ($P \leq 0.05$). The incidence of 1st and 2nd antibiotic therapies for UBRD (P <

0.01) and medical cost were decreased for calves dosed Lactipro ($P < 0.05$). Dosing cattle with Lactipro allows for accelerated adaption to high-concentrate diets, decreases reliance on roughages, and improves health during the receiving period.

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List of Abbreviations

A:P ratio	acetate:propionate ratio
ADG	average daily gain
BRD	bovine respiratory disease
BW	body weight
CFU	colony forming unit
CLA	conjugated linoleic acid
CP	crude protein
CS	corn silage
DFM	direct fed microbial
DM	dry matter
DMI	dry matter intake
DOF	days on feed
F:G	feed:gain
Fig	figure
G:F	gain:feed
GI tract	gastrointestinal tract
HCW	hot carcass weight
KPH	kidney, pelvic, and heart fat
LM	longissimus muscle
M. elsdenii	Megasphaera elsdenii
NEFA	non-esterified fatty acid
OTU	operational taxonomic units
P	phosphorus
peNDF	physically effective neutral detergent fiber
UBRD	undifferentiated bovine respiratory disease
USDA	United State Department of Agriculture

VFA	volatile fatty acid
WCGF	wet corn gluten feed
YG	yield grade

Chapter 1 : A REVIEW OF THE LITERATURE

Introduction

Acidosis is caused by a decrease in ruminal pH associated with increased organic acid production, which occurs when highly-fermentable feedstuffs are consumed in excess, too rapidly, or without proper adaptation of ruminal microflora. Lactate production can increase rapidly and accumulate due to the rapid growth rate of *Streptococcus bovis*, which is a lactate-producing bacterium that has been linked with acidosis (Nagaraja and Lechtenberg, 2007). Lactate-utilizing bacteria are capable of converting lactate into VFAs, which have a higher pka than lactate; however, populations of lactate-utilizing bacteria are low in unadapted animals (Huber et al., 1976) and have a slower growth rate than *Streptococcus bovis* (Therion et al., 1982). Acidosis may be classified as subacute, which is associated with an increase in organic acid production and a subsequent decrease in ruminal pH. Clinical signs may not be present during subacute acidosis, but performance is typically compromised. Clinical symptoms are present during the acute form of acidosis where ruminal pH has dropped and remained low for an extended period of time. Elevated ruminal concentrations of lactic acid are typically observed during acute acidosis (Nagaraja and Lechtenberg, 2007). As a result of low pH rumen motility is decreased, intake is depressed, and performance is negatively impacted (Slyter, 1976). Acidic conditions in the rumen can damage the rumen epithelium and may hinder absorption for several months thereafter (Krehbiel et al., 1995c). Absorption of organic acids can lower blood pH, resulting in metabolic acidosis, which can lead to death (Owens et al., 1998). Several secondary conditions are associated with acidosis including liver abscess, laminitis, polioencephalomalacia, displaced abomasums, ketosis, and bloat (Brent, 1976; RAGFAR, 2007).

Megasphaera elsdenii is an anaerobic Gram-negative bacterium that was first isolated from the rumen of sheep in 1953 (Elsden and Lewis, 1953). It has been estimated that *M. elsdenii* accounts for 60 to 80% of the lactic acid metabolism in the rumen (Counotte et al., 1981) making it an ideal candidate for aiding in the mitigation of lactic acidosis.

Elam (1976) identified 5 critical time periods when cattle are at the highest risk of acidosis, including starting cattle on concentrate diets, increasing the amount of concentrates in the diet, weather changes, when cattle are on high-concentrate rations for an extended period of time, and times of extreme hunger due to feeding problems.

The intention of this literature review is to summarize data on methods of controlling or preventing acidosis in ruminants with an emphasis on *Megasphaera elsdenii* and its role in prevention of acidosis.

Acidosis Prevention Methods

Adaptation to concentrate diets

New cattle coming into feedlots typically are accustomed to forage-based diets and must be transitioned to high-concentrate diets to achieve optimal feedlot performance. To aid in preventing acidosis during this diet change, cattle must be gradually transitioned from forage-based diets to concentrate-based diets, allowing ruminal microorganisms to adapt from fiber digestion to the digestion of starches and sugars. It is recommended that the adaptation period be 2 to 3 wk to effectively decrease the risk of acidosis (Brown et al., 2006). In cattle switched directly from a high-forage diet to a high-concentrate diet, *Streptococcus bovis* populations have been shown to increase 67-fold (Tajima et al., 2001), whereas when cattle are transitioned gradually, increases in *Streptococcus bovis* are less dramatic (2-fold) and are more stable

(Fernando et al., 2010). Populations of *Megasphaera elsdenii* (lactate-utilizing bacteria) do not appreciably increase until the concentrate portion reaches 60-70% of the diet (Huber et al., 1976; Mackie and Gilchrist, 1979; Fernando et al., 2010). Bevans et al. (2005) adapted heifers from a 40% barley diet to a 94% barley diet in 3 or 15 d and showed a lower risk of acidosis in cattle placed on the 15 d adaptation program. On the first day of feeding the 65% barley diet, heifers adapted over 3 d had greater ruminal pH variability and greater time spent below pH 5.6 compared to heifers adapted in 15 d. Some heifers on the 3-d adaptation program developed subacute acidosis (pH < 5.6 for greater than 12 h). On the first day of feeding the 90% concentrate diet, ruminal pH variability and area under the curves (pH < 6.2, 5.6, or 5.2) was again greater for heifers adapted in 3 d; however, subacute acidosis was experienced by animals in both adaption regimens. On the second day of feeding the 90% barley diet, some heifers in the 3 d group experienced acute acidosis (pH < 5.2 for greater than 6 h). On d 1 of feeding the 90% concentrate diet, lactate accumulated in 2 animals on the 3 d adaptation program and 1 animal on the 15 d adaptation program.

Two-ration blending is another method for adapting cattle to high-concentrate diets without having the burden of mixing multiple step-up diets. Only a starting diet and a finishing diet must be milled in this system. Adaption to the finishing diet occurs by incrementally decreasing the percentage of the starting diet and increasing the percentage of the finishing diet of total feed offered daily. Feedlot performance and carcass traits were similar between heifers adapted to the finishing diet by a 28 d step-up program and a 28 d two-ration blending program (Burken et al., 2010).

Restricted feeding of a high concentrate diet is a means of adapting cattle to a high-concentrate diet without having the added labor of batching several different diets over a 2- to 3-

wk period. Choat et al. (2002) conducted two feeding studies, one with yearlings steers and another with steer calves, evaluating restricted intake during the adaptation period. Intake of all restricted cattle was decreased during the adaptation period, which would be expected, but was also lower over the entire feeding period compared to the control cattle despite feeding the restricted cattle *ad libitum* following the adaptation period. Variation in DMI was generally reduced during the adaptation period for restricted intake cattle. In yearling steers, ADG, feed efficiency, and carcass characteristics were not different; however, restricting intake in calves resulted in lower ADG, final BW, and carcass weights. Utilizing a limited maximum intake feeding strategy, Bartle and Preston (1992) adapted steers to a high-concentrate diet by limiting the maximum feed offering to 2.1, 2.3, 2.5, and 2.7 (LO) or 2.3, 2.5, 2.7, and 2.9 (HI) times maintenance energy requirements for the first 4 wk. Cattle were adapted to the finishing diet by feeding each adaptation diet for 7 d before moving to the next diet in the program. Steers on the LO adaptation program had lower DMI than steers offered adaptation diets *ad libitum*; however, steers on the HI adaptation program had similar DMI to the *ad libitum* steers during the first 28 d. The lower DMI of the LO steers resulted in a tendency for improved efficiency compared to *ad libitum* steers. Over the entire feeding period there was a trend for steers on the LO adaptation program to have greater ADG than *ad libitum* steers, but there were no other differences in DMI, or gain efficiency. Although improvements in performance were observed during the first 28 d on feed, which may suggest that the incidence of acidosis was decreased, there was a trend for increased clumping of ruminal papillae in steers transitioned using the LO program. Damage to ruminal papillae is associated with acidic condition in the rumen (Huntington, 1988) suggesting that cattle in the LO program may have experienced acidosis.

Gradually reducing the roughage and increasing the concentrate portion of the diet, limiting intake of a high-concentrate diet, or a combination of replacing roughages with concentrates and limiting intake, can be effectively used to transition cattle to a high-concentrate diet. Regardless of the method used to adapt cattle, a minimum of 14 d is generally recommended to prevent decreased performance during the adaptation period (Brown et al., 2006).

Intake and bunk management

Bunk management can be used as a tool to decrease the risk of acidosis. Two commonly used feeding systems are *ad libitum* and restricted feeding. *Ad libitum* feeding provides the animal constant access to feed, targeting a small portion of residual feed remaining in the bunk when fresh feed is delivered (Schwartzkopf-Genswein et al., 2003). Alternatively, feed intake may be restricted, resulting in consumption of all of the feed offered prior to the subsequent feeding (Galyean, 1999). *Ad libitum* feeding typically leads to more frequent and smaller meals, which decreases variability in the rumen environment (Erickson et al., 2003). Providing feed *ad libitum* may increase the chance for sorting, increase variation in daily intake, and provides the opportunity for over consumption (Pritchard and Burns, 2003). Restricted feeding maintains a more constant pen intake between days with the goal of preventing overconsumption, but results in consumption of larger less frequent meals, which can cause a decrease in ruminal pH and increase the risk of acidosis (Schwartzkopf-Genswein et al., 2003). Using radio frequency ear tags, Gibb et al. (1998) monitored bunk attendance during the finishing period when cattle were fed *ad libitum*, limit fed with one feeding per day, or limit fed with two feedings per day. They observed an increase in the frequency of bunk attendance with *ad libitum* and limit-fed with two feedings compared to limit-fed with one feeding. When diets are limit fed, increasing the number of feedings per day may spread consumption out over a larger portion of the day, potentially decreasing meal size and risk of acidosis. Erickson et al. (2003) observed an increase in meal size and an increased rate of consumption when using a clean bunk management program compared to *ad libitum* bunk management. Although the steers fed using clean bunk management consumed larger meals more rapidly, average ruminal pH and duration of pH < 5.6 were not different from those of *ad libitum* fed steers; however, daily variation in ruminal pH was greater for steers managed with the clean bunk system.

Intake fluctuation or altering the amount of concentrates consumed on a daily basis has been associated with increased risk of acidosis (Pritchard and Bruns, 2003). Schwartzkopf-Genswein et al. (2004) found that fluctuating daily feed offerings by 10% decreased average ruminal pH and increased the amount of time pH was < 5.8, suggesting an increased risk of acidosis compared to a constant daily feed offering. Although the 10% fluctuation in feed offerings decreased mean ruminal pH, there were no effects on finishing performance. Soto-Navarro et al. (2000) limit fed steers a 90% concentrate diet at 90% of *ad libitum* intake once daily or twice daily and intake was held constant or fluctuated by 10%. Ruminal pH was < 6.2 for longer when steers were fed once daily and intake was fluctuated compared to steers fed a constant intake once daily. However, ruminal pH of steers fed twice daily with a 10% fluctuation in daily intake was < 6.2 for fewer hours compared to steers fed twice daily at a constant intake. Increasing the number of feedings may reduce the risk of acidosis when there is fluctuation in daily intake; however, fluctuating daily intake decreased digestibility and VFA production, which may result in decreased performance (Soto-Navarro et al., 2000).

The feeding of total mixed ration diets is common practice in most commercial feedlots and dairies in an attempt to provide appropriate balance of nutrients. Despite this, feed sorting can be a problem when animals preferentially consume smaller particles (grains) or larger particles (roughages). Sorting of diets can be affected by forage particle size, quantity of forages in the diet, and the amount of feed offered (DeVries et al., 2007; Suarez-Mena et al., 2012). In dairy lactation diets, decreasing the roughage content from 62.3% to 50.7% (DM basis) increased sorting of the diet, favoring consumption of smaller particle sizes and discouraging forage consumption (DeVries et al., 2007). DeVries et al. (2008) observed increased sorting against long particles as forage content of the diet decreased. In addition, they observed a decrease in ruminal pH as sorting increased. Furthermore, following an acidosis challenge cows fed a low forage diet altered their sorting pattern, by selecting for longer particles. Increasing the particle size of grass hay or oat straw included in the diet at 50% and 75% (DM), respectively, increased dietary sorting by dairy cows (Suarez-Mena et al., 2012). Therefore processing roughages to a smaller particle size may decrease sorting; however, excessive processing of roughages will decrease chewing and saliva production lowering the buffering capacity of the rumen (Owens et al., 1998).

The addition of moisture in the form of water or liquid supplements is one method for decreasing dietary sorting. Leonardi et al. (2005) added water to an 80% DM diet to achieve 64.4% DM and found that sorting by lactating cows decreased. The addition of water to a high moisture diet (56.3% DM) increased sorting by lactating dairy cows (Felton and DeVries, 2010). Sorting can be decreased by restricting the amount of feed offered, resulting in consumption of all the feed offered (Pritchard and Burns, 2003). The downfall to this approach is that cattle are typically fed in a pen environment, which means that although the pen as a whole did not sort the diet, individual animals have the opportunity to preferentially consume one component of the diet over the other. This not only impacts the animals that are sorting through the diet, but also leaves an unbalanced diet remaining in the bunk for other animals.

Sorting can increase the risk of acidosis, however altering the percentage of forage in the diet, forage particle size, or conditioning the ration with water or liquid feeds may decrease sorting.

Dietary factors

Grains vary in their fermentability and therefore in their ability to induce acidosis. Elam (1976) suggested that of the grains commonly used in ruminant diets, wheat was the most problematic, followed by corn and sorghum, with barley resulting in the lowest occurrence of acidosis. It is common practice to process grains by reducing particle size, steam flaking, or high-moisture ensiling. Processing grains increases the availability of starch to the ruminal microorganisms, increasing rate and extent of ruminal fermentation (Rémond et al., 2004; Owens and Zinn, 2005). When grains are processed DMI and ADG decrease, although the latter to a lesser degree, which improves efficiency (Owens et al., 1997). The decrease in DMI has been attributed to acidosis due to the positive correlation between starch availability and rate of fermentation (Owens et al., 1998). Ruminal starch digestion is greater for steam-flaked and high-moisture grains than for dry-rolled or whole grains (Owens and Soderlund, 2006). Increasing the extent to which grains are processed by decreasing particle size or flake density increases the risk of acidosis. Decreasing the flake density of sorghum decreased ruminal pH, increased the time spent below pH 5.5 and 5.0, and increased the risk and severity of acidosis (Reinhardt et al., 1997). Decreasing the particle size of dry-rolled corn increased ruminal starch digestion in lactating dairy cow diets (Rémond et al., 2004). Therefore, under conditions where acidosis is a problem decreasing the extent of grain processing or selecting grains with a slower rate of fermentation should decrease the risk of acidosis, but efficiency may be sacrificed. Decreasing the rate and extent of ruminal fermentation could decrease the risk of acidosis. Iqbal et al. (2012) steeped barley in lactic acid to try to slow the rate and extent of ruminal starch fermentation to decrease the risk of acidosis. This treatment decreased ruminal VFA concentration, increased ruminal pH, and maintained DMI and milk production (Iqbal et al., 2012). Altering the type of grain, the type of processing, or the extent of processing are all viable methods for reducing the risk of acidosis; however, altering these factors will have an impact of animal performance and should be considered when making such changes.

Inclusion of roughages in the diet with sufficient particle size stimulates chewing, which increases saliva production, improving the buffering capacity of the rumen and decreasing the risk of acidosis (Owens et al., 1998). The quantity of roughages fed in feedlot diets is typically low to achieve optimum performance and efficiency; however, they typically are not eliminated completely (Vasconcelos and Galyean, 2007). The addition of small quantities of roughages in highly fermentable diets improves performance and efficiency compared to the same diets devoid of roughages. When highly fermentable grains such as dry-rolled wheat are fed, increasing roughages from 0% to 7.5% improved DMI, ADG, and feed efficiency. These improvements were not seen when less fermentable grain sources (dry-rolled corn or dry-rolled sorghum) were fed (Stock et al., 1990). Improved performance associated with increased dietary roughage may be attributable to a decrease in acidosis through a dilution effect, increased saliva production, and improved rumen function (Allen, 1997). Increasing dietary forage from 8% to 16% (DM basis) tended to increase rumen pH in steers fed a high concentrate diet (Calderon-

Cortes and Zinn, 1996). Physically effective fiber is defined as the portion of the diet that stimulates chewing activity (Allen, 1997). Increasing physically effective NDF (peNDF) can be achieved by either increasing the forage content of the diet, increasing the particle length of the forage, or by increasing both forage content and particle length (Yang and Beauchemin, 2007). Increasing the peNDF by increasing forage content is the most effective way to increase peNDF provided that the particle of sufficient length. Increasing particle length can be effective when high forage diets are fed (Yang and Beauchemin, 2007). Increasing the chop length of alfalfa silage increased eating time, chewing, the number of meals consumed each day, and time spent ruminating by lactating dairy cows (Krause et al., 2002). Increasing forage particle size also increased ruminal pH and decreased area and time ruminal pH was < 5.8 (Krause et al., 2002). Allen (1996) found that dietary NDF was poorly correlated to ruminal pH, however forage NDF was correlated to ruminal pH, therefore when formulating diets for lactating dairy cattle forage NDF should be considered. The effectiveness of forages to decrease the risk of acidosis is dependent on are their ability to stimulate chewing and saliva production for buffering and their dilution of nonstructural carbohydrates in the diet (Allen, 1997). It must be taken into account that by increasing the forage content of the diet by replacing more fermentable feedstuffs may decrease performance due to decreasing dietary energy content. Another consideration when increasing particle length is the impact on sorting of the diet and its impact on acidosis.

Typically, by-product feeds have had a large portion of their starch removed thus concentrating the fiber, proteins, and minerals (Erickson, 2012). When grain by-products are used in the diet replacing a portion of the grain (starch) performance is similar or improved compared to diets containing grain without the by-products (Erickson, 2012). This improvement in performance has been suggested to be a result of decreasing the occurrence of acidosis

(Nagaraja and Lechtenberg, 2007). Wet corn gluten feed (WCGF) typically includes a portion of the condensed fermented corn extractives which can contain significant amounts of lactic acid. The feeding of WCGF may aid in the establishment of a lactate-utilizing bacterial populations, better equipping the rumen environment for dealing with lactate production during fermentation (DiLorenzo and Galyean, 2010). In addition the risk of acidosis may be decreased by using by-products to replace a portion of the grain in the diet thereby decreasing the starch content of the diet. Scott et al., (2003) suggested that when WCGF was added at 22% or 32% of dietary DM in place of a portion of the grain, the grain could be processed more extensively without increasing the risk of acidosis. Krehbiel et al., (1995a) evaluated the use of WCGF to decrease acidosis by administering 100% dry-rolled corn, 50% dry-rolled corn and 50% WCGF, or 100% WCGF through a rumen cannula. When WCGF was administered, ruminal lactate concentrations increased during the first 3 h and ruminal pH was lower compared to administering 100% dry-rolled corn. Despite the initial decrease in pH when WCGF was administered, at the end of the 24 h sampling period ruminal pH was greater for steers administered WCGF than steers administered 100% dry-rolled corn. Steers started on a 8% alfalfa hay and 86.5% WCGF (DM) diet were adapted to a 35% WCGF diet over 19 d by replacing WCGF with dry-rolled corn. Performance was similar between steers adapted using a traditional step-up program where forage was replaced by dry-rolled corn and steers adapted using WCGF, therefore the authors concluded that utilizing WCGF was a viable alternative for diet adaptation (Krehbiel et al., 1995a). A similar adaptation program utilizing wet distiller's grains with solubles (WDGS) was evaluated by Rolfe et al. (2010) where the initial diet contained 87.5% (DM) WDGS and was decreased to 35% of the diet DM by incrementally replacing WDGS with dry-rolled corn over 28 d. Ruminal pH and DMI were decreased when cattle were adapted to a finishing diet with

WDGS compared to cattle adapted using a traditional program. Schneider et al. (2012) utilized a traditional step-up program decreasing alfalfa hay from 45% to 7.5% over 28 d or used a complete feed containing WCGF and minimal amounts of roughage, which was initially fed at 100% of the diet and then incrementally replaced by the finishing diet over 28 d. Over the 28 d average ruminal pH, pH variance, time pH was < 5.6, and area < 5.6 were not different, but area below pH < 5.3 was less for steers adapted using the complete WCGF diet. The use of by-product feeds in finishing diets and during adaptation to high-concentrate diets may not decrease the risk of acidosis, but it provides an alternative to traditional adaptation programs and decreases reliance on roughages.

Fat can be added to the diet to increase energy content of the diet and replace a portion of the grain in the diet. It has been proposed that the addition of fat to the diet may help reduce the incidence of acidosis by replacing starch (Elam, 1976) or by coating the starch particles slowing the rate of fermentation (Huffman et al., 1992b). Kellems et al. (1989) mixed different fat sources with ground barley and observed decreased *in vitro* DM and starch disappearance as fat increased from 5% to 10%. Results of *in vivo* studies have not shown a decrease in rate or extent of ruminal starch fermentation when fats are added. Adding up to 6% fat to the dry-rolled corn finishing diets decreased ruminal pH and reduced performance with no effect on starch fermentation (Krehbiel et al., 1995b). Zinn (1989) observed a decrease in ruminal fiber digestion, but ruminal starch digestion was not affected by the addition of fat to steam-rolled barley diets. Similarly, Plascencia et al. (2003) observed no effect of fat on ruminal starch digestion. Adding fat to ruminant diets increases energy density of the diet, however it does not appear to be a good method for preventing acidosis.

Weather

Weather events such as extreme temperatures, changes in temperature, rain, or snow can impact eating patterns and therefore predispose cattle to acidosis. High temperatures cause a decreased intake, decreased meal frequency, and decreased meal size, which can last 3 to 4 d before the animal can begin to adapt and increase intake (Hahn et al., 1990). The DMI of lactating cows exposed to heat stress was decreased 30% compared with cows exposed to a moderate temperature (Wheelock et al., 2010). Following this period of lower intake the return of milder temperatures and increase in intake may put the animal at risk of acidosis, which may explain why it is thought by some that occurrence of acidosis increases during warmer months (Elam, 1976). Intake is typically increased during cold weather to compensate for increased metabolic demand (Young, 1983; Young, 1981). This increased intake may increase the risk of acidosis; however, gut motility is increased and with it passage rate, which may decrease some of the risk of acidosis by shifting digestion from the rumen to the lower GI tract (Young, 1981). Precipitation in the form of snow or rain can impact pen conditions and alter the eating behavior of cattle ultimately impacting intake. Muddy pens can decrease intake 15 to 30% depending on the severity of the mud (NRC, 2000).

Changes in temperature and poor pen conditions result in intake fluctuation, which may put cattle at a greater risk of acidosis, particularly when high concentrate diets are fed. Altering diet composition to reduce fermentability during periods of abrupt weather changes may help to alleviate some of the increased risk of acidosis.

Ionophores

Ionophores are commonly added to ruminant diets to modify ruminal fermentation and improve efficiency (Bergen and Bates, 1984). Dennis et al. (1981) determined that lasalocid and monensin, two commonly used ionophores, were effective at inhibiting growth of major lactate-producing bacteria and had little to no impact on the growth of lactate-utilizing bacteria. The preferential alteration of ruminal microflora by these ionophores inhibits the growth of some of the major lactate-producing bacteria, decreasing the risk of lactate accumulation and subsequently acidosis. Administered at 1.3 mg/kg BW, monensin or lasalocid were effective at preventing lactic acidosis following a glucose challenge; however, only lasalocid was effective at a lower dose of 0.65 mg/kg BW (Nagaraja et al., 1982). Laidlomycin propionate, another ionophore, was less effective at preventing acidosis during a grain challenge; however, it did decrease intake variation during the adaptation period, which may aid in the prevention of subacute acidosis (Bauer et al., 1995). The addition of monensin to a 100% concentrate diet elicited a greater improvement in ADG and feed efficiency than when added to a diet containing 7.5% roughage. Monensin also elicited a greater improvement in performance when dry-rolled wheat was used as the grain source compared to dry-rolled corn (Stock et al., 1990). These results would suggest that as the risk of acidosis increases so does the response elicited by monensin. In accelerated adaptation programs of only 7 d, monensin did not prevent a rapid decrease in intake, on d 7 when the 95% concentrate finishing diet was first fed (Burrin et al., 1988). However, when cattle were adapted over 14 d, feeding monensin prevented a depression in intake when the 95% concentrate diet was fed and daily intake variation was decreased (Burrin et al., 1988). Erickson et al. (2003) observed an increase in the number of meals and a decrease in the size of meals when monensin was fed using a restricted or slick bunk feeding program; however, they did not observe an effect on eating pattern when diets with monensin were fed *ad libitum*. Smaller meals consumed more frequently should provide for a more stable ruminal environment, decreasing the risk of excess organic acid production. Ionophores alter ruminal bacterial populations; modulate eating behavior and ruminal pH of cattle fed high-concentrate diets, which may aid in decreasing the occurrence of acidosis.

Subacute acidosis is a problem in dairy cattle. Feeding monensin as a premix or in a time released capsule has had limited impact on ruminal pH during a subacute acidosis challenge, but has had a positive impact on DMI and milk production (Mutsvangwa et al., 2002). Similar to these findings, Mullins et at. (2012) found no effect of monensin on ruminal pH during the transition period. Eating behavior of dairy cows during subacute acidosis may be altered by feeding monensin (Lunn et al., 2005; Duffield et al., 2007; Mullins et al., 2012). Lunn et al. (2005) observed an increase in meal frequency during subacute acidosis and the subsequent recovery period, which may aid in stabilizing the rumen environment. Postpartum DMI of dairy cows was not affected by monensin inclusion; however, there was a tendency for eating behavior to be altered postpartum with meal frequency tending to increase when monensin was fed (Mullins et al., 2012). A meta-analysis conducted by Duffield et al. (2007) revealed an overall trend for reduced DMI when monensin was fed to dairy cows.

Monensin has limited effects on ruminal pH in dairy cows with induced subacute acidosis. This may occur because subacute acidosis is commonly associated with a decrease in pH due to VFA accumulation as opposed to lactate accumulation which is commonly observed in acute acidosis (Owens, 1998). Therefore, the impact of monensin on lactate-producing bacterial populations may not play a critical role in subacute acidosis prevention. Despite limited impacts on ruminal pH, monensin does appear to alter intake and intake behavior, which may provide a means for decreasing the risk of acidosis.

Starch fermentation inhibitors

The rate and extent to which starch is fermented in the rumen impacts the relative risk of acidosis therefore, slowing the rate or decreasing the extent of ruminal fermentations should decrease the risk of acidosis (Owens et al., 1998). Feeding α-amylase/glucosidase inhibitors may provide a means of decreasing the rate of fermentation resulting in a more stable rumen environment. McLaughlin et al. (2009a) fed acarbose (α-amylase/glucosidase inhibitor), monensin, or sodium bicarbonate to steers and challenged them with starch induced acidosis. Acarbose altered the rate of fermentation, decreased VFA production and prevented acute acidosis (defined as $pH < 4.5$ and lactate > 50 mM) more effectively than monensin or sodium bicarbonate (McLaughlin et al., 2009a). Additionally, supplementing lactating cow diets, known to induce subacute acidosis with acarbose increased DMI and increased percent milk fat (McLaughlin et al., 2009b). Blanch et al. (2010) fed acarbose to lactating cows and found that mean ruminal pH were greater and hours with ruminal $pH < 5.6$ were fewer for cows fed acarbose. Dry matter intake and total VFA production were not impacted by the feeding of acarbose (Blanch et al., 2010).

Acarbose appears to effectively alter the rate and extent of ruminal starch digestion increasing ruminal pH and preventing acidosis. Limited data exist regarding the effect of acarbose on total tract digestion and impacts on performance.

Buffers

Endogenous buffers are secreted into the rumen through saliva, which is stimulated by chewing, and through VFA absorption by means of bicarbonate dependent VFA uptake (Dijkstra et al., 2012). The endogenous buffers help to stabilize ruminal pH, however when high concentrate diets are fed chewing is minimal due to low dietary forage content and the relatively small particle size of the diet, both which decrease the amount of buffer secreted. Exogenous buffers such as sodium bicarbonate can be added to the diet to increase the buffering capacity of the rumen. Buffers have been used to help prevent depression in ruminal pH, aiding in fiber digestion, and preventing acidosis. Fulton et al. (1979) administered 500 or 1000 mL of a sodium and potassium hydroxide mixture to steers fed a 90% wheat diet. Steers receiving the mixture had greater ruminal pH, increased DMI, and reduced lactate concentrations compared to control steers. Lambs fed large quantities of barley supplemented with sodium bicarbonate consumed more than lambs fed barley alone (Fulton et al., 1979). Providing a buffer to stabilize ruminal pH following grain engorgement increased the amount of grain that could be consumed before intake decreased (Phy and Provenza, 1998). The addition of both sodium bicarbonate and lasalocid resulted in the greatest improvement in intake of lambs offered barley grain (Phy and Provenza, 1998). By adding both sodium bicarbonate and lasalocid to the barley you provide a buffer for the increased VFA production and suppress lactate producing bacteria, further aiding in the prevention of acidosis. Cows given free choice access to a supplement block containing a buffer had higher ruminal pH and less time and area of ruminal pH < 5.6 compared to cows without access to the buffer (Krause et al., 2009). Feeding sodium bicarbonate in lactation diets containing 70%, 50%, 30%, or 0% concentrate decreased the amount of time pH was < 6, and the impact was most pronounced in the 70% concentrate diet (Stokes and Bull, 1986). Feeding an exogenous buffer can help to prevent or delay a decrease in ruminal pH following overconsumption of concentrates.

Direct fed microbials

Different approaches have been taken when administering direct fed microbials (DFM) to ruminants with the goal of decreasing acidosis. One approach is to feed a lactate-producing bacterium to create chronic exposure to lactate, thereby stimulating a population of lactate-utilizing bacteria (Huffman et al., 1992a; Nocek et al, 2002). An alternative approach is to provide lactate-utilizing bacteria in an attempt to prevent lactate accumulation (Kung and Hession, 1995; McDaniel, 2009).

Huffman et al. (1992a) dosed cannulated steers with *Lactobacillus acidophilus* (5×10^6, 5×10^8, or 5×10^{10}) twice daily via the rumen cannula and saw a decrease in time ruminal pH was < 6.0 during an acidosis challenge when *Lactobacillus acidophilus* (5×10^8) was administered compared to control steers. A specific combination of *Enterococcus faecium*, *Lactobacillus plantarum*, and *Saccharomyces cerevisiae* was administered daily to lactating dairy cows via ruminal cannulas at levels of 10^5, 10^6, and 10^7 CFU/mL of rumen fluid. Ruminal pH was monitored (Nocek et al., 2002). Administering the mixture at a level of 10^5 CFU/mL elevated ruminal pH, however increasing the dose decreased ruminal pH. Nocek et al. (2002) speculated that the higher doses of microorganisms resulted in a greater production of lactate then could be effectively utilized by the lactate-utilizing populations, therefore decreasing ruminal pH. An *In vitro* study utilizing a continuous culture fermentor showed no benefits to ruminal pH when supplemented with *Propionibacterium*, *Enterococcus faecium*, or *Enterococcus faecium* plus yeast compared to the control culture (Yang et al., 2004). Furthermore, lactate-utilizing bacterial counts were lower for cultures inoculated with *Propionibacterium* and *Enterococcus faecium* plus yeast cultures compared to the control culture. In studies feeding a highly-fermentable barley-based feedlot diet, *Enterococcus faecium* fed alone or in combination with yeast did not increase ruminal pH. The author speculated that Enterococcus *faecium* feed along may have increased the risk of acidosis as minimum pH was lower for this group than the control (Beauchemin et al., 2003). Ghorbani et al. (2002) fed *Propionibacterium* or *Propionibacterium* plus *Enterococcus faecium* to steers fed an 87% steam-rolled barley diet and found no differences in ruminal pH or lactate concentrations compared to steers receiving no DFM. Feeding lactate-producing bacteria at certain levels has shown to increase ruminal pH; however, overfeeding of lactate-producing bacteria may decrease ruminal pH.

Megasphaera elsdenii is the most prominent ruminal lactate-utilizing bacterium in cattle fed high concentrate diets (Counotte, 1981) and therefore has been evaluated as a DFM for prevention of acidosis. Kung and Hession (1995) demonstrated that *in vitro* culture tubes containing a highly fermentable substrate and inoculated with *M. elsdenii* maintained a higher pH and prevented lactate accumulation compared to culture tubes that were not inoculated. McDaniel (2009) found that cannulated steers feed a high-concentrate diet and inoculated with *M. elsdenii* had higher ruminal pH and lower lactate concentrations than their counterparts that did not receive *M. elsdenii*. Henning et al. (2010b) evaluated 9 strains of *M. elsdenii in vivo* and determined that there was variability between strains but, certain strains were capable of decreasing the degree to which ruminal pH was depressed and preventing lactate accumulation during an acidosis challenge. Furthermore, Henning et al. (2010b) evaluated the most promising strains *in vivo* where they were capable of establishing viable populations, modulating pH, and preventing lactate accumulation during an acidosis challenge. Klieve et al. (2003) inoculated steers with 5.5×10^{12} CFU *M. elsdenii* YE34 and 3×10^{4} CFU of *B. Fibrisolvens* YE44 prior to adaptation to high-concentrate diet. Klieve et al. (2003) did not observe any differences between inoculated and control steers with regard to rumen pH or lactate concentrations; however, ruminal populations of *M. elsdenii* were not detectable in control steers until d 12 of the study, but were present in inoculated steers throughout the study. Administering *M. elsdenii* to lactating dairy cows decreased the amount of time ruminal pH was < 5.6 compared to cows that did not receive *M. elsdenii* (Aikman et al., 2011). Administering *M. elsdenii* to cattle prior to the introduction of high-concentrate diets has been shown to increase DMI, ADG, and improve efficiency in feedlot cattle (Henning et al., 2010a; Meissner et al., 2010). In dairy cattle administering *Megasphaera elsdenii* increased DMI, milk production, and milk production efficiency (Aikman et al., 2011; Henning et al., 2011; Meissner et al., 2010). *Selenomonas ruminantium* is another ruminal lactate-utilizing bacterium. Cook et al. (1977) dosed heifers with *P. asaccharolyticus*, *S. ruminantium*, or *M. elsdenii*. Following dosing, heifers were placed on an 80% concentrate diet for 21 d. Heifers dosed with *M. elsdenii* or *S. ruminantium* had lower ADG and poorer feed efficiency than did the control heifers, while *P. asaccharolyticus* improved performance compared to the control. Ruminal pH and lactate concentrations were not monitored, however despite the abrupt change from a hay diet to an 80% concentrate diet, the author noted that none of the animals exhibited signs of acidosis (Cook et al., 1977). Inoculating ruminants with a lactate-utilizing bacterium prior to introduction of grains may decrease the risk of acidosis by preventing ruminal pH depression and ruminal lactate accumulation.

Role of *Megasphaera elsdenii* in preventing acidosis

Metabolism of M. elsdenii

Megasphaera elsdenii is capable of utilizing carbohydrates, simple sugars, amino acids, and lactic acid for growth. The substrate fermented and the strain of *M. elsdenii* impact the profile of fermentative end products produced. Table 1-1 summarizes the end products produced by 7 different strains of *M. elsdenii* grown on glucose or lactate. Butyrate and valerate were produced by all strains when glucose was provided as a substrate, while caproate and formate were produced by most of the strains and acetate by only two strains. All strains produced acetate, propionate, and butyrate from lactate and most of the strains also produced valerate while only one strain produced caproate. The key difference between the metabolism of glucose and lactate by all evaluated strains of *M. elsdenii* is the production of propionate from lactate, but not from glucose. *M. elsdenii* utilizes the acrylate pathway to convert lactate into propionate. *M. elsdenii* strain NIAH-1102 grown on lactate produced a similar VFA profile to other strains; however when both acrylate and lactate were added to the medium propionate was produced in the greatest concentration (Hino and Kuroda, 1993). In addition, Hino and Kuroda (1993) noted that adding acrylate to a glucose medium resulted in the fermentation of glucose to propionate. This illustrates the importance of the acrylate pathway in the production of propionate by *M. elsdenii*. Propionate is desirable because it is a direct intermediate of gluconeogenesis in cells making it a precursor for glucose production.

M. elsdenii also plays a role in protein catabolism; although protein is not a predominant substrate used for growth by *M. elsdenii* it may be beneficial to other rumen bacteria by supplying NH_3 and branched-chain fatty acids (Wallace, 1986).

Some strains of *M. elsdenii* have been shown to increase ruminal CLA, a product of incomplete biohydrogenation of linoleic acid by ruminal microorganisms. *M. elsdenii* YJ-4 was shown to increase trans-10, cis-12 CLA (Kim et al., 2002), which has been linked to milk fat depression in dairy cows (Baumgard et al., 2000). Kim et al. (2002) observed a large variation among strains of *M. elsdenii* for CLA production *in vitro* and Margarida et al. (2007) found that the 2 strains evaluated in his study didn’t produce any CLA from linoleic acid.

M. elsdenii is capable of converting lactic acid, an undesirable product of ruminal fermentation, into a desirable product (VFA). This aids in preventing ruminal pH reduction due to the higher pKa (pH at which buffering capacity is maximized) of VFA compared to lactate (Owens et al., 1998). *M. elsdenii* plays a minor role in both protein fermentation and CLA production, which may have impacts on other microorganisms and milk composition.

Substrate utilization and growth

M. elsdenii is capable of utilizing several substrates; therefore, substrate preference plays a key role in *M. elsdenii's* ability to prevent lactate accumulation in the ruminal environment, where a variety of substrates are readily available under normal conditions. Hino et al. (1994) observed that *M. elsdenii* NIAH 1102 preferred lactate as a substrate and would not use glucose until lactate was depleted to very low levels. Marounek et al. (1989) also observed that lactate was utilized in preference to glucose in the 4 different strains of *M. elsdenii* evaluated, although the extent to which lactate was depleted before glucose began to be utilized as a substrate varied among strains. In contrast, Russell and Baldwin, (1979) observed that *M. elsdenii* B159 had a high affinity for glucose and low affinity for lactate and maltose. Most strains of *M. elsdenii* appear to prefer lactate as a substrate and in the case of strain B159, despite the lower affinity for lactate there were no catabolic effects on lactate utilization because both glucose and lactate were utilized simultaneously (Russell and Baldwin, 1978). The priority to which *M. elsdenii* metabolizes lactate in the presents of other substrates appears to be strain specific, but the ability of some strains to exclusively utilize lactate prior to other substrates making it well suited for use in the mitigation of lactic acidosis.

Optimum pH for growth of *M. elsdenii* appears to be around 6, however *M. elsdenii* ATCC 25940 grew over a pH range of 4.6 to 7.8 (Therion et al., 1982). In contrast Russell et al.

(1979) found that no growth occurred for *M. elsdenii* B159 at or below pH 5.6. Therion et al. (1982) also determined that the optimum growth rate on different substrates is pH dependent. They observed optimum growth on lactate at pH 5 - 6.5 but, outside this range growth was optimized on glucose. *M. elsdenii* bacteria are able to maintain growth at relatively low pH by allowing their internal pH to decrease. This allows them to avoid some of the extra energy expenditure associated with maintaining a larger pH gradient between internal and environmental pH (Russell, 1991). At low pH the activity of H^+-ATPase increases allowing the cell to move more H^+ out of the cell maintaining internal pH (Miwa et al., 1997). More recent work shows that genome shuffling may provide a means for altering pH tolerance and VFA profiles of *M. elsdenii* (Long et al., 2012).

M. elsdenii preferentially utilizes lactate and has the ability to survive at a relatively low pH, giving it an advantage over other lactate utilizing microorganisms. Lactate utilization is suppressed in *Selenomonas ruminantium* when sucrose or glucose is present (Russell and Baldwin, 1978), which is typically the case under conditions conducive to acidosis. In addition *Selenomonas ruminantium* and *Veillonella alcalescens*, another ruminal lactate-utilizing bacterium, are relatively acid-sensitive (Mackie and Gilchrist, 1979), reducing their efficacy when high-concentrate diets are fed.

Antibiotic and ionophore Susceptibility

Antibiotics and ionophores are commonly used in livestock diets to improve health and performance. Ionophores particularly are fed to modify ruminal fermentation therefore it is important to understand how these may affect *M. elsdenii*. Resistance of *M. elsdenii* B159 to Lasalocid, Monensin, Narasin, Salinomycin, Avoparcin, Thiopeptin, Tylosin, and Virginiamycin at a concentration of 48 µg/mL was demonstrated by Nagaraja and Taylor (1987). Kalachniuk et al. (1995) evaluated 4 different strains of *M. elsdenii* (L8, L C1, AW 106, and J1) and found them to be resistant to commonly used antibiotics tested (bacitracin, monensin, tylosin, and virginiamycin) at 10 or 50 mg/L. This allows for *M. elsdenii* to be utilized over a wide range of situations without detrimentally affecting its efficacy.

Diet adaptation

When cattle are adapted from high-forage to high-concentrate diets a substantial change in the ruminal microbial populations occurs. Fernando et al. (2010) found approximately 398 operational taxonomic units (OTU's) occurred in cattle fed high-forage diets and approximately 315 OTU's present when cattle were fed high-concentrate diets. Despite the overall number of OTU's being similar there were only 24 OTU's shared between animals on high-forage and high-concentrate diets. During a diet change the population size of a bacterial species may increase or decrease by several fold. Starch fermenting bacteria such as *S. ruminantium*, *Streptococcus bovis*, and *Lactobacilli* can proliferate rapidly when starches and soluble sugars become available (Nagaraja and Titgemeyer, 2007). *Streptococcus bovis* is one of the fastest growing ruminal bacterium (Hungate, 1979; Therion et al., 1982) and as ruminal pH decreases production of lactate by *Streptococcus bovis* increases, due to an increase in lactate dehydrogenase (Russell and Hino, 1985). *Streptococcus bovis* has been identified as the primary bacteria responsible for initiation of the sequence that eventually leads to acidosis (Nagaraja and Lechtenberg, 2007). The growth rate of *M. elsdenii* is slower than that of *Streptococcus bovis* (Therion et al., 1982), which leads to the accumulation of lactate when high-concentrate diets are fed without proper adaptation. *Streptococcus bovis* populations in cows switched directly from a high-forage diet to a high-concentrate diet increased 67-fold followed by a substantial reduction by d 28 (Tajima et al., 2001). Gradual adaptation to concentrate diets is used to control the growth of *Streptococcus bovis* and allow time for *M. elsdenii* to establish adequate populations to prevent lactate accumulation. In cattle transitioned from a forage diet to a high-concentrate diet, populations of *Streptococcus bovis* increased 2-fold and then stabilized. This was followed by an 11-fold increase in *M. elsdenii* followed by an approximately 6-fold decrease (Fernando et al., 2010). The stabilization of *Streptococcus bovis* following a 2-fold increase demonstrates how a step-up program can decrease the risk of acidosis. Increases in *M. elsdenii* are not typically observed until the concentrate portion of the diet reaches 60-70% (Huber et al., 1976; Fernando et al., 2010). Mackie and Gilchrist (1979) found that a diet containing approximately 71% highly fermentable substrate was required to maintain adequate growth of lactate-utilizing bacteria. In dairy cows the presence of *M. elsdenii* during adaptation may provide additional benefits beyond prevention of lactate accumulation. In cows where *M. elsdenii* populations are low, overall VFA production is decreased and cows are more likely to experience ketosis (Wang et al., 2012). Wang et al. (2012) suggested that hypoglycemia, another condition common during the transition period, may be a result of decreased propionate production due to low populations of *M. elsdenii*.

Administering *M. elsdenii* prior to the introduction of concentrates into ruminant diets may provide a means of shorting the time required for adaptation and decreasing the risk of acidosis during the adaptation period. Decreasing the time required to adapt ruminants to high-concentrate diets would decrease the amount of roughages required, which are expensive per unit of energy and difficult to handle (Britton and Stock, 1986). Additionally, adaptation diets are less energy dense then high-concentrate diets therefore providing these diets as soon as possible is attractive from a performance stand point.

***Inoculation with M. elsdenii* (*in vitro*)**

Kung and Hession (1995) inoculated *in vitro* tubes containing rumen fluid from a steer consuming a hay diet, with a low (8.7×10^5 CFU/mL) or high (8.7×10^6 CFU/mL) dose of *M. elsdenii* B159 and a highly fermentable substrate containing soluble starch and glucose. Initial pH was 6.6 and decreased to 4.8 in control tubes while the pH of inoculated tubes decreased to 5.3 and 5.4 for the low and high level doses respectively. The pH of control tubes remained lower than the inoculated tubes for the remainder of the 24 h fermentation. Inoculating with *M. elsdenii* prevented lactate accumulation in both the low and high levels (< 8 mM), whereas in the control tubes lactate accumulated and remained at about 40 mM. Inoculating cultures with *M. elsdenii* increased butyrate and decreased acetate and propionate concentrations compared to the control cultures. Following the initial 24 h incubation, cultures were transferred into fresh media to evaluate the ability of *M. elsdenii* to withstand a second challenge. Lactate again accumulated in the control cultures, and *M. elsdenii* was able to prevent the accumulation of lactate. In contrast to the initial 24 h incubation, pH of both control and inoculated cultures dropped to 4.8. The authors speculated that since lactate accumulation was prevented in the inoculated cultures the drop in pH may have been due to an accumulation of VFA in the closed system.

Henning et al. (2010b) evaluated 9 isolates of *M. elsdenii* to determine their ability to maintaining pH and preventing lactate accumulation. As expected, there was variability among strains on their effectiveness in maintaining pH and preventing lactate accumulation. Of the 9 strains evaluated, CH3 and CH7 appeared to be the most effective at maintaining pH. These strains had the lowest values for time spent below pH 6.0 and below pH 5.0. Although time spent below these critical values was longer for CH4 (NCIMB 41125) it was not statistically different. Despite strain CH3's ability to maintained pH, it was not very effective at preventing lactate accumulation; therefore, the authors determined strains CH4 and CH7 to be the best candidates for use in acidosis prevention.

Inoculation with M. elsdenii (in vivo)

Henning et al. (2010b) followed up the *in vitro* work with strains CH4 and CH7 with a metabolism study where they administered 100-mL dose containing 10^{11} CFU/mL of *M. elsdenii* strain CH4 or CH7 to sheep prior to inducing a grain challenge. Rumen pH of inoculated sheep remained above 5.5 and greater than the control sheep. Sheep receiving strain CH4 had ruminal pH above 6.0 by 24 h post grain challenge. Lactate concentrations were lower in sheep inoculated with *M. elsdenii* compared to the control. Intake was greater in inoculated sheep following the grain challenge, which would be expected since pH was greater and lactate concentration were lower in inoculated sheep. The strains selected during the *in vitro* work effectively established populations *in vivo* and prevented pH depression and lactate accumulation following a grain challenge.

McDaniel (2009) dosed fistulated steers with 10 mL (1.62×10^9 CFU), 100 mL (1.62×10^{10} CFU), or 1000 mL (1.62×10^{11} CFU) of culture containing *M. elsdenii* NCIMB 41125. Steers were fed a 66% concentrate diet for 6 d followed by an 80% concentrate diet for 4 d and a 94% concentrate diet thereafter. Administering *M. elsdenii* increased populations of undifferentiated *M. elsdenii*, which remained higher than control steers until d 10 when populations groups were similar. Over the first 24 h, inoculated steers had lower DMI and higher ruminal pH than control steers. Ruminal pH remained lower in control steers until d 4 at which time all steers had similar ruminal pH and DMI. When steers were placed on the 80% concentrate diet pH was not different between *M. elsdenii* and control steers, however DMI was higher for control steers. On the first day of feeding the final 94% concentrate diet, ruminal pH of all steers dropped below 5.5. In control steers ruminal lactate concentrations peaked on day 3 at approximately 50 mM. Ruminal lactate concentrations were lower in inoculated steers until d 4. Following 5 d of feeding the 94% concentrate diet, another challenge was initiated by fasting the steers for 24 h and then offering the 94% concentrate diet again. By the end of the sampling period pH was below 5.5 in all steers except the group receiving 1000 mL of *M. elsdenii* and DMI was again greater in control steers.

Klieve et al. (2003) inoculated steers previously fed a hay diet with 5.5×10^{12} CFU of *M. elsdenii* YE34 and 3×10^{4} CFU of *B. fibrisolvens* YE44. Steers were adapted to a high concentrate diet by feeding a 45% rolled-barley diet for 2 d followed by a 60% rolled-barley diet for 2 d and finally a 75% rolled-barley diet for the remaining 12 d of the experiment. Ruminal pH and lactate concentrations were not different between treatments. Populations of *M. elsdenii* were not detectable ($< 10^{4}$) until grain was introduced or steers were inoculated with *M. elsdenii*. Populations of *M. elsdenii* remained low in control steers until d 12 of the study and did not reach those of inoculated steers until the end of the study. Although there were no differences in ruminal pH or lactate concentrations, it was evident that inoculated populations of *M. elsdenii* were able to thrive in the rumen. The author noted that 1 animal in the control group was not included in the data set due to low intakes of hay and a severe case of acidosis following the first day of grain feeding. Unlike the other animals in the study, *Streptococcus bovis* increased by 100-fold following the introduction of grain, and ruminal lactate concentrations peaked at 103.5 mM.

Henning et al. (2010a) dosed steers with *M. elsdenii* NCIMB 41125 and transitioned them to a 94% concentrate diet over 20 d. Ruminal lactate concentrations were 20.8 and 10.1 mM/L on d 2 and 3 respectively for control steers. Conversely, average ruminal lactate concentrations were 0.34 and 0.45 mM/L on d 2 and 3 respectively for steers dosed with *M. elsdenii*. Despite the large numerical differences in lactate concentration between control and inoculated steers on d 2 and 3 they were not significantly different (P = 0.13 and P = 0.14 respectively). The VFA profile suggested a shift toward butyrate in steers given *M. elsdenii* at the expense of acetate and propionate.

Zebeli et al. (2012) dosed cows averaging 170 days in milk with 35 mL of *M. elsdenii* ATCC 25940 (10^8 CFU/mL) to determine the effects on VFA profiles, ruminal pH, blood plasma non-esterified fatty acids (NEFA) concentrations, and blood cholesterol levels. As a proportion of total VFA butyrate and valerate increased at the expense of acetate, isobutyrate, and isovalerate when cows were administered *M. elsdenii*. *M. elsdenii* tended to increase the preprandial molar proportion of propionate and, therefore, decrease the A:P ratio. Ruminal pH decreased following feeding, but remained above 5.8 in both treatment groups. Blood plasma non-esterified fatty acids were decreased and cholesterol tended to increase when cows received *M. elsdenii*. Decreasing plasma NEFA concentrations is indicative of an improved energy balance (Overton and Waldron, 2004).

M. elsdenii can be introduced into the rumen and establish viable populations capable of preventing lactate accumulation. Studies that did not show differences in pH and lactate between treated and control animals may be a result of the diets used and their respective ability to induce lactic acidosis. There is large variability in individual animal susceptibility to acidosis (Brown et al., 2006), which may be a factor in studies where small numbers of animals are used. In cases where difference were not observed there was little evidence of an acidosis challenge occurring in the control animals. Inoculating ruminants with *M. elsdenii* shifts VFA production toward butyrate at the expense of acetate and propionate.

Performance

Cook et al. (1977) dosed heifers with *P. asaccharolyticus, S. ruminantium, M. elsdenii*, or the medium that the bacteria were grown in. Following dosing, heifers were placed on an 80% concentrate diet for 21 d. Heifers dosed with *Megasphaera elsdenii* or *S. ruminantium* had lower ADG and poorer feed efficiency than the control heifers dosed only with the medium, while *P. asaccharolyticus* improved performance compared to the control. Despite the abrupt change from a hay diet to an 80% concentrate diet, the author noted that none of the animals exhibited signs of acidosis.

In a follow-up study to Klieve et al. (2003), Klieve et al. (2012) orally dosed steers with *M. elsdenii* YE34 and *Ruminococcus bromii* YE282. Steers were then adapted to a high concentrate diet over a 13 d period using 2 adaptation diets and a finishing diet. Performance was measured for 70 d, and no differences were found in DMI, ADG, or feed efficiency. Similar to their previous study, inoculation with *M. elsdenii* resulted in a stable ruminal population of *M. elsdenii* for the duration of the study. In contrast to their previous work, *M. elsdenii* populations in the control steers were relatively high by d 3 of the study, whereas in previous work it was not developed until later in the feeding period. The author speculated that the rapid establishment of *M. elsdenii* in control steers may have been a result of cross contamination between treatment groups despite efforts to prevent it.

Leeuw et al. (2009) evaluated the effect of *M. elsdenii* NCIMB 41125 on the performance of steers fed a high or low roughage diet. Dietary roughage levels for the high and low groups were 8% and 2% respectively. Half of the steers in each roughage level were dosed with 200 mL of medium containing 10^9 CFU/mL *M. elsdenii*. Steers receiving *M. elsdenii* had greater ADG and improved feed conversion during wk 3-5; however, there were no differences over the entire study wk 1-13. There was no interaction between *M. elsdenii* and roughage level for any performance measures during the 13 wk study. Carcass characteristics were not impacted by dosing steers with *M. elsdenii* during the finishing period. Morbidity tended to be lower in steers dosed with *M. elsdenii*. Steers on the low roughage without *M. elsdenii* had the highest incidence of bloat and diarrhea.

Henning et al. (2010) evaluated the ability of *M. elsdenii* NCIMB 41125 to prevent lactic acidosis in lambs and steers when transitioned from a forage diet to a concentrate-based diet. Lambs were fed a hay based diet with a protein mineral supplement prior to d 1 of the study. On d 1 lambs were given *ad libitum* accesses to a concentrate mix based on whole corn and *ad libitum* access to hay or restricted access to hay (200 g, as fed) per lamb daily. On d 1 and 2 of concentrate feeding, a portion of the lambs on each diet were given a 100-mL dose of *M. elsdenii* (10^6 CFU/mL in the rumen). Lambs dosed with *M. elsdenii* had greater intake (as fed) of concentrates and lower intake of hay (as fed). Overall intake (as fed) was greater for lambs dosed with *M. elsdenii*. Ruminal pH was higher and lactate was lower for lambs dosed with *M. elsdenii* during the first 14 d on feed. Despite the greater intake, there were no differences in ADG or dressing percent between treatments. In the second experiment, 12 steers were transitioned to from a hay diet to a 94% concentrate diet over 20 d. Steers received no *M. elsdenii*, a low dose of *M. elsdenii* (1.72×10^9 CFU/dose), a medium dose of *M. elsdenii* (1.72×10^{10} CFU/dose), or a high dose of *M. elsdenii* (1.72×10^{11} CFU/dose). Dosing steers with *M. elsdenii* increased daily intake and improved ADG over control steers during the 37-d study.

Drouillard et al. (2012) evaluated the effect of a dose of *M. elsdenii* NCIMB 41125 on performance and carcass traits of steers transitioned to high-concentrate diets over a 17-d or 8-d period. Dry matter intake, ADG, and feed efficiency were not different between treatments.

There was a trend for greater carcass weights and carcass adjusted ADG in steers dosed with *M. elsdenii*, but other carcass measures were not affected by treatment.

Another study conducted by McDaniel (2009) evaluated the use of *M. elsdenii* NCIMB 41125 in a natural finishing program. There were no differences in finishing performance between the control and *M. elsdenii* cattle. Carcass traits were similar between treatments with the exception of a trend for an increase in the number of yield grade 5 cattle in the *M. elsdenii* group. Liver abscesses and animal health were not different between treatments.

Administering *M. elsdenii* to ruminants prior to the introduction of highly fermentable feedstuffs has shown to improve performance in some studies. In several cases authors noted that signs of acidosis were not observed in inoculated or control animals, indicating that acidosis may not have been a problem in these studies, therefore reducing the efficacy of *M. elsdenii*.

M. elsdenii in dairy Cows

Hagg et al. (2010) utilized 60 multiparous Holstein-Friesian dairy cows to evaluate the effect of *M. elsdenii* NCIMB 41125 on intake, health, and milk production of cows fed a low or high concentrate diet. Cows were administered a 250-mL oral dose containing 10^9 CFU of *M. elsdenii*/mL on d 2, 10, and 20 post-partum. Cows were culled from the study and replaced with another cow if DMI or milk production declined by 30% of the previous weeks value for 5 or more consecutive days. This resulted in 12 cows being culled from the control group and 2 cows being culled from the *M. elsdenii* group. Dosing cows with *M. elsdenii* did not affect DMI, daily variance in DMI, milk production, milk composition, or feed efficiency (kg milk/kg DMI). When just the high-concentrate diet was evaluated, milk fat percent was decreased in the *M. elsdenii* group. The lack of differences due to *M. elsdenii* administration may be a result of the culling program utilized in this study. It appears that health was improved by administering *M. elsdenii* based on the greater number of cows culled from the control group, however we don't know if this difference was significant.

Aikman et al. (2011) administered *M. elsdenii* NCIMB 41125, to ruminally-fistulated cows, on d 3 and d 12 post-partum to determine its effect on DMI and milk production. Dry matter intake and milk production were not different between the control and *M. elsdenii* cows, but feed efficiency improved as a result of administering *M. elsdenii*. Milk fat concentrations were lower for *M. elsdenii* cows compared to control cows but other milk components were not affected. Over the entire study rumen pH was not affected by treatment and the treatment × day interaction was not significant. Control cows had a much greater fluctuation in rumen pH and a greater total amount of time pH was below 5.6 compared to cows administered *M. elsdenii*. In general, ruminal lactate concentrations were low at 2.13 mM/L and 2.23 mM/L for control and *M. elsdenii* cows respectively.

Zebeli et al. (2012) used 8 ruminally fistulated cows that averaged 170 d in milk to evaluate the impact of a daily 35-mL dose of *M. elsdenii* ATCC 25940 containing 10^8 CFU/mL live bacteria on DMI, milk yield, and milk composition. Dry matter intake was not affected by treatment. There were trends for increased milk protein and somatic cell counts and a decrease in lactose percentage associated with administering *M. elsdenii*, while milk fat was unaffected by treatment. Overall milk yield was unaffected and composition was generally not impacted by daily *M. elsdenii* administration.

Henning et al. (2011) dosed Holstein cows on a 60 or 70% concentrate ration with *M. elsdenii* NCIMB 41125 (250-ml dose containing 10^{11} CFU/*M. elsdenii*) on the day of parturition, d 10, and d 20. Cows dosed with *M. elsdenii* tended to have higher milk yields than cows that did not receive *M. elsdenii*. When the 60% concentrate diet was fed dosing cows with *M. elsdenii* increased milk fat percent compared to control cows, but when the 70% concentrate diet was fed there were no differences in milk fat percent. Body weight was increased (54 kg) as a result of dosing cows with *M. elsdenii*, the greatest difference was observed in cows fed the 70% concentrate diet.

Inoculating dairy cows prior to increasing concentrates in the diet improved weight gain and milk production. Impacts on milk components were mixed, but were generally unaffected by administering *M. elsdenii*.

Summary

Decreasing the risk of acidosis requires proper diet formulation and management of cattle during the introduction to and feeding of high-concentrate diets. Adapting cattle to high-concentrate diets by incrementally decreasing the forage and increasing concentrates is a common practice; however, alternative adaptation programs using restricted feeding or by-product feeds may be viable alternatives. Management of cattle intake and the processing of feedstuffs are critical to maintaining a stable ruminal environment and decreasing the risk of acidosis. The amount of roughages included in the diet impacts both performance and ruminal pH. Feed additives such as ionophores and direct-fed microbials are another means of decreasing the risk of acidosis through altering eating behavior and ruminal microbial populations when high-concentrate diets are fed.

Inoculated populations of *M. elsdenii* are capable of establishing and maintaining growth both *in vitro* and *in vivo* during an acidosis challenge. This may be beneficial in mitigating the lag in growth between lactate-producing and lactate-utilizing microorganisms in the rumen. Eliminating this lag time may allow for more rapid adaptation to high-concentrate diets while maintaining adequate ruminal pH and preventing lactate accumulation in both beef and dairy production systems. The use of *M. elsdenii* has shown to have both performance and health benefits during the transition period from high-forage to high-concentrate diets. Furthermore, shortening the adaptation period for feedlot cattle simplifies the management of such diet changes. Acidosis is a multifaceted problem with a continuum of degrees that must be managed using a multifaceted approach combining both management practices and dietary factors into preventative measures.

Literature Cited

Aikman, P. C., P. H. Henning, D. J. Humphries, and C. H. Horn. 2011. Rumen pH and fermentation characteristics in dairy cows supplemented with *Megasphaera elsdenii* NCIMB 41125 in early lactation. J. Dairy Sci. 94:2840-2849.

Allen, M. S. 1997. Relationship between fermentation acid production in the rumen and the requirement for physically effective fiber. J. Dairy Sci. 80:1447-1462.

Bartle, S. J. and R. L. Preston. 1992. Roughage level and limited maximum intake regimens for feedlot steers. J. Anim. Sci. 70:3293-3303.

Bauer, M. L., D. W. Herold, R. A. Britton, R. A. Stock, T. J. Klopfenstein, and D. A. Yates. 1995. Efficacy of laidlomycin propionate to reduce ruminal acidosis in cattle. J. Anim. Sci. 73:3445-3454.

Baumgard, L. H., B. A. Corl, D. A. Dwyer, A. Saebo, and D. E. Bauman. 2000. Identification of the conjugated linoleic acid isomer that inhibits milk fat synthesis. Am. J. Physiol. Regul. Integr. Comp. Physiol. 278:R179-R184.

Beauchemin, K. A., W. Z. Yang, D. P. Morgavi, G. R. Ghorbani, W. Kautz, and J. A. Z. Leedle. 2003. Effects of bacterial direct-fed microbials and yeast on site and extent of digestion, blood chemistry, and subclinical ruminal acidosis in feedlot cattle. J. Anim. Sci. 81:1628-1640.

Bergen, W. G. and D. B. Bates. 1984. Ionophores: their effect on production efficiency and mode of action. J. Anim. Sci. 58:1465-1483.

Bevans, D. W., K. A. Beauchemin, K. S. Schwartzkopf-Genswein, J. J. McKinnon, and T. A. McAllister. 2005. Effect of rapid or gradual adaptation on subacute acidosis and feed intake by feedlot cattle. J. Anim. Sci. 83:1116-1132.

Blanch, M., S. Calsamiglia, M. Devant, and A. Bach. 2010. Effects of acarbose on ruminal fermentation, blood metabolites and microbial profile involved in ruminal acidosis in lactating cows fed a high-carbohydrate ration. J. Dairy Res. 77:123-128.

Britton, R. A. and R. A. Stock. 1986. Acidosis, rate of starch digestion and intake. Okla. Agric. Exp. Stn. MP-121. pp 125-137.

Brown, M. S., C. H. Ponce, and R. Pulikanti. 2006. Adaptation of beef cattle to high-concentrate diets: Performance and ruminal metabolism. J. Anim. Sci. 84:E25-E33.

Burken, D. B., J. L. Wahrmund, B. P. Holland, C. R. Krehbiel, and C. J. Richards. 2010. Two ration blending vs. traditional step-up adaptation to finishing diets: Performance and carcass characteristics. Plains Nutrition Council Spring Conference, San Antonio, TX. P. 99 (Abstr.)

Burrin D. G., R. A. Stock, and R. A. Britton. 1988. Monensin level during grain adaptation and finishing performance in cattle. J. Anim. Sci. 66:513-521.

Calderon-Cortes, J. F. and R. A. Zinn. 1996. Influence of dietary forage level and forage coarseness of grind on growth performance and digestive function in feedlot steers. J. Anim. Sci. 74:2310-2316.

Choat, W. T., C. R. Krehbiel, M. S. Brown, G. C. Duff, D. A. Walker, and D. R. Gill. 2002. Effects of restricted versus conventional dietary adaptation on feedlot performance, carcass characteristics, site and extent of digestion, digesta kinetics, and ruminal metabolism. J. Anim. Sci. 80:2726-2739.

Cook, M. K., J. H. Cooley, J. D. Edens, D. D. Goetsch, N. K. Das, and T. L. Huber. 1977. Effect of ruminal lactic acid-utilizing bacteria on adaptation of cattle to high-energy rations. Am. J. Vet. Res. 7:1015-1017.

Counotte, G. H. M., R. A. Prins, R. H. A. M. Janssen, and M. J. A. De Bie. 1981. Role of *Megasphaera elsdenii* in the fermentation of DL-[2-13C] lactate in the rumen of dairy cattle. Appl. Environ. Microbiol. 42:649-655.

Dennis, S. M., T. G. Nagaraja, and E. E. Bartley. 1981. Effects of lasalocid or monensin on lactate-producing or –using rumen bacteria. J. Anim. Sci. 52:418-426.

DeVries, T. J., K. A. Beauchemin, and M. A. G. von Keyserlingk. 2007. Dietary forage concentration affects the feed sorting behavior of lactating dairy cows. J. Dairy Sci. 90:5572-5579.

DeVries, T. J., F. Dohme, and K. A. Beauchemin. 2008. Repeated ruminal acidosis challenges in lactating dairy cows at high and low risk for developing acidosis: feed sorting. J. Dairy Sci. 91:3958-3967.

Dijkstra, J., J. L. Ellis, E. Kebreab, A. B. Strathe, S. Lopeze, J. France, and A. Bannink. 2012. Ruminal pH regulation and nutrition consequences of low pH. Anim. Feed Sci. Technol. 172:22-33.

DiLorenzo, N. and M. L. Galyean. 2010. Applying technology with newer feed ingredients in feedlot diets: Do the old paradigms apply? J. Anim. Sci. 88:E123-E132.

Drouillard, J. S., P. H. Henning, H. H. Meissner, and K-J. Leeuw. 2012. *Megasphaera elsdenii* on the performance of steers adapting to a high-concentrate diet, using three or five transition diets. S. Afr. J. Anim. Sci. 42(No. 2): 195-199.

Duffield, T. F., A. R. Rabiee, and I. J. Lean. 2008. A meta-analysis of the impact of monensin in lactating dairy cattle. Part 2. Production effects. J. Dairy Sci. 91:1347-1360.

Elam, C. J. 1976. Acidosis in feedlot cattle: practical observations. J. Anim. Sci. 43:898-901.

Elsden, S.R. and D. Lewis. 1953. The production of fatty acids by a gram-negative coccus. J. Biochem. 55:183-189.

Erickson G. E., C. T. Milton, K. C. Fanning, R. J. Cooper, R. S. Swingle, J. C. Parrott, G. Vogel, and T. J. Klopfenstein. 2003. Interaction between bunk management and monensin concentration on finishing performance, feeding behavior, and ruminal metabolism during an acidosis challenge with feedlot cattle. J. Anim. Sci. 81:2869-2879.

Erickson, G. E. 2012. Utilization of feed co-products from wet or dry milling for beef cattle. Biofuel co-products as livestock feed: opportunities and challenges. Food and Agriculture Organization of the United Nations p. 77-99

Felton, C. A. and T. J. DeVries. 2010. Effect of water addition to a total mixed ration on feed temperature, feed intake, sorting behavior, and milk production of dairy cows. J. Dairy Sci. 93:2651-2660.

Fernando, S. C., H. T. Purvis II, F. A. Najar, L. O. Sukharnikov, C. R. Krehbiel, T. G. Nagaraja, B. A. roe, and U. Desilva. 2010. Rumen microbial population dynamics during adaptation to a high-grain diet. App. Environ. Microbiol. 76:7482-7490.

Forsberg, C. W. 1978. Nutritional characteristics of *Megasphaera elsdenii*. Can. J. Microbiol. 24:981-985.

Fulton, W. R., T. J. Klopfenstein, and R. A. Britton. 1979. Adaptation to high concentrate diets by beef cattle. II. Effect of ruminal pH alteration on rumen fermentation and voluntary intake of wheat diets. J. Anim. Sci. 49:785-789.

Galyean, M. L. 1999. Review: Restricted and programmed feeding of beef cattle—definitions, application and research results. Prof. Anim. Sci 15:1-6.

Ghorbani, G. R., D. P. Morgavi, K. A. Beauchemin, and J. A. Z. Leedle. 2002. Effects of bacterial direct-fed microbials on ruminal fermentation, blood variables, and microbial populations of feedlot cattle. J. Anim. Sci. 80:1977-1985.

Gibb, D. J, T. A. McAllister, C. Huisma, and R. D. Wiedmeier. 1998. Bunk attendance of feedlot cattle monitored with radio frequency technology. Can. J. Anim. Sci. 78:707-710.

Hagg, F. M., L. J. Erasmus, P. H. Henning, and R. J. Coertze. 2010. The effect of a direct fed microbial (*Megasphaera elsdenii*) on the productivity and health of Holstein cows. S. Afr. J. Anim. Sci. 40(2):101-112.

Hahn, G. L., R. A. Eigenberg, J. A. Nienaber, and E. T. Littledike. 1990. Measuring physiological response of animals to environmental stressors using a microcomputer-based portable data logger. J. Anim. Sci. 68:2658-2665.

Henning, P. H., C. H. Horn, K-J. Leeuw, H. H. Meissner, and F. M. Hagg. 2010a. Effect of ruminal administration of lactate-utilizing strain *Megasphaera elsdenii* (Me) NCIMB 41125 on abrupt or gradual transition from forage to concentrate diets. Anim. Feed Sci. Technol. 157:20-29.

Henning, P. H., C. H. Horn, D. G. Steyn, H. H. Meissner, F. M. Hagg. 2010b. The potential of *Megasphaera elsdenii* isolates to control ruminal acidosis. Anim. Feed Sci. Technol. 157:13-19.

Henning, P. H., L. J. Erasmus, H. H. Meissner, and C. H. Horn. 2011. The effect of dosing *Megasphaera elsdenii* NCIMB 41125 (Me) on lactation performance of multiparous Holstein cows. S. Afr. J. Anim. Sci. 41:156-160.

Hino, T. and S. Kuroda. 1993. Presence of lactate dehydrogenase and lactate racemase in *Megasphaera elsdenii* grown on glucose or lactate. Appl. Environ. Microbiol. 59(1):255-259.

Hino, T., K. Shimada, and T. Maruyama. 1994. Substrate preference in a strain of *Megasphaera elsdenii*, a ruminal bacterium, and its implications in propionate production and growth competition. App. Environ. Microbiol. 60:1827-1831.

Huber, T. L., J. H. Cooley, D. D. Goetsch, and N. K. Das. 1976. Lactic acid-utilizing bacteria in ruminal fluid of a steer adapted from hay feeding to a high-grain ration. Am. J. Vet. Res. 37:611-613.

Huffman R. P., K. K. Karges, T. J. Klopfenstein, R. A. Stock, R. A. Britton, And L. D. Roth. 1992a. The effect of *Lactobacillus acidophilus* on subacute ruminal acidosis. J. Anim. Sci. 70 (Suppl. 1):87(Abstr.).

Huffman, R. P., R. A. Stock, M. H. Sindt, and D. H. Shain. 1992b. Effect of fat type and forage level on performance of finishing cattle. J. Anim. Sci. 70:3889-3898.

Hungate, R. E. 1979. Evolution of a microbial ecologist. Annu. Rev. Microbiol. 33:1-22.

Huntington, G. B. 1988. Acidosis. In: The Ruminant Animal: Digestive Physiology and Nutrition. Waverland Press. Inc. Englewood Cliffs, NJ. p. 474-480.

Iqbal, S., S. J. Terrill, Q. Zebeli, A. Mazzolari, S. M. Dunn, W. Z. Yang, and B. N. Ametaj. 2012. Treating barley grain with lactic acid and heat prevented sub-acute ruminal acidosis and increased milk fat content in dairy cows. Anim. Feed. Sci. Technol. 172:141-149.

Kalachniuk, G. I., M. A. Marounek, O. G. Savka, S. B. Chon, and K. Bodia. 1995. Metabolic response of pure strains of ruminal bacteria to various antibiotics. Russian Agri. Sci. 4:1-7.

Kellems, R. O., F. W. Weaver, C. M. Baysingar, and M. V. Wallentine. 1989. The effect of applying 57 commercial lipid sources at 5% and 10% rates on rumen *in vitro* disappearance of dry matter and starch components of barley. In: Proc. Western Section, Am. Society of Anim. Sci., Bozeman, MT. 40:410-413

Kim, Y. J., R. H. Liu, J. L. Rychlik, and J. B. Russell. 2002. The enrichment of a ruminal bacterium (*Megasphaera elsdenii* YJ-4) that produces the trans-10, cis-12 isomer of conjugated linoleic acid. App. Environ. Microbiol. 92:976-982.

Klieve, A. V., D. Hennessy, D. Ouwerkerk, R. J. Forster, R. I. Mackie, and G. T. Attwood. 2003. Establishing populations of *Megasphaera elsdenii* YE 34 and *Butyrivibrio fibrisolvens* YE 44 in the rumen of cattle high grain diets. App. Environ. Microbiol. 95:621-630.

Klieve, A. B., S. R. McLennan, and D. Ouwerkerk. 2012. Persistence of orally administered *Megasphaera elsdenii* and *Ruminococcus bromii* in the rumen of beef cattle fed a high grain (barley) diet. Anim. Prod. Sci. 52:297-304.

Krause, K. M., D. K. Combs, and K. A. Beauchemin. 2002. Effects of forage particle size and grain fermentability in midlactation cows. II. Ruminal pH and chewing activity. J. Dairy. Sci. 85:1947-1957.

Krause, K. M., D. V. Dhuyvetter, and G. R. Oetzel. 2009. Effect of a low-moisture buffer block on ruminal pH in lactating dairy cattle induced with subacute ruminal acidosis. J. Dairy Sci. 92:352-364.

Krehbiel, C. R., R. A. Stock, D. W. Herold, D. H. Shain, G. A. Ham, and J. E. Carulla. 1995a. Feeding wet corn gluten feed to reduce subacute acidosis in cattle. J. Anim. Sci. 73:2931-2939.

Krehbiel, C. R., R. A. Stock, D. H. Shain, C. J. Richards, G. A. Ham, R. A. McCoy, T. J. Klopfenstein, R. A. Britton, and R. P. Huffman. 1995b. Effect of level and type of fat on subacute acidosis in cattle fed dry-rolled corn finishing diets. J. Anim. Sci. 73:2438-2446.

Krehbiel, C. R., R. A. Britton, D. L. Harmon, T. J. Wester and R. A. Stock. 1995c. The effects of ruminal acidosis on volatile fatty acid absorption and plasma activities of pancreatic enzymes in lambs. J. Anim. Sci. 73:3111-3121.

Krehbiel, C. R., S. R. Rust, G. Zhang, and S. E. Gilliland. 2003. Bacterial direct-fed microbials in ruminant diets: Performance response and mode of action. J. Anim. Sci. 81:E120-132.

Kung, L. Jr. and A. O. Hession. 1995. Preventing *in vitro* lactate accumulation in ruminal fermentation by inoculation with *Megasphaera elsdenii*. J. Anim. Sci. 73:250-256.

Leeuw, J-K. F. K. Siebrits, P. H. Henning, and H. H. Meissner. 2009. Effect of *Megasphaera elsdenii* NCIMB 41125 drenching on health and performance of steers fed high and low roughage diets in the feedlot. S. Afr. J. Anim. Sci. 39(4):337-348.

Leonardi, C., F. Giannico, and L. E. Armentano. 2005. Effect of water addition on selective consumption (sorting) of dry diets by dairy cattle. J. Dairy Sci. 88:1043-1049.

Long, M., L. Peng, W. K. Zhang, Y. Zhang, Y. Guo, S. H. Yang, Z. Wang, and G. W. Liu. 2012. Genome shuffling of *Megasphaera elsdenii* for improving acid-tolerance and propionate production. Afr. J. Microbiol. Res. 6(18):4041-4047.

Lunn, D. E., T. Mutsvangwa, N. E. Odongo, T. F. Duffield, R. Bagg, P. Dick, G. Vessie, and B. W. Mcbride. 2005. Effect of monensin on meal frequency during sub-acute ruminal acidosis in dairy cows. Can. J. Anim. Sci. 85:247-249.

Mackie, R. I. and F. M. C. Gilchrist. 1979. Changes in lactate-producing and lactate-utilizing bacteria in relation to pH in the rumen of sheep during stepwise adaptation to a high-concentrate diet. Appl. Environ. Microbiol. 38:422-430.

Margarida, R. G. M., L. C. Chaudhary, L. Figueres, and R. J. Wallace. 2007. Metabolism of polyunsaturated fatty acids and their toxicity to the microflora of the rumen. Antonie Van Leeuwenhoek. 91:303-314.

Marounek, M., K. Fliegrova, and S. Bartos. 1989. Metabolism and some characteristics of ruminal strains of *Megasphaera elsdenii*. Appl. Environ. Microbiol. 55:1570-1573.

McLaughlin, C. L., A. Thompson, K. Greenwood, J. Sherington, and C. Bruce. 2009a. Effect of acarbose on acute acidosis. J. Dairy. Sci. 92:2758-2766.

McLaughlin, C. L., A. Thompson, K. Greenwood, J. Sherington, and C. Bruce. 2009b. Effect of acarbose on milk yield and composition in early-lactation dairy cattle fed a ration to induce subacute ruminal acidosis. J. Dairy Sci. 92:4481-4488.

Meissner, H. H., P. H. Henning, C. H. Horn, K-J. Leeuw, F. M. Hagg and G. Fouché. 2010. Ruminal acidosis: A review with detailed reference to the controlling agent *Megasphaera elsdenii* NCIMB 41125. S. Afr. J. Anim. Sci. 40:79-100.

Miwa, T., H. Esaki, J. Umemori, and T. Hino. 1997. Activity of H+ -ATPase in ruminal bacteria with special reference to acid tolerance. Appl. Environ. Microbiol. 63(6)-2155-2158.

Mullins C. R., L. K. Mamedova, M. J. Brouk, C. E. Moore, H. B. Green, K. L. Perfield, J. F. Smith, J. P. Harner, and B. J. Bradford. 2012. Effects of monensin on metabolic parameters, feeding behavior, and productivity of transition dairy cows. J. Dairy. Sci. 95:1323-1336.

Mutsvangwa, T., J. P. Walton, J. C. Plaizier, T. F. Duffield, R. Bagg, P. Dick, G. Vessie, And B. W. McBride. 2002. Effects of a monensin controlled-release capsule or premix on attenuation of subacute ruminal acidosis in dairy cows. J. Dairy Sci. 85:3454-3461.

Nagaraja, T. G., T. B. Avery, E. E. Bartley, S. K. Roof, and A. D. Dayton. 1982. Effect of lasalocid, monensin, or thiopeptin on lactic acidosis in cattle. J. Anim. Sci. 54:649-658.

Nagaraja, T. G. and M. B. Taylor. 1987. Susceptibility and resistance of ruminal bacteria to antimicrobial feed additives. Appl. Environ. Microbiol. 53(7):1620-1625.

Nagaraja, T. G. and K. F. Lechtenberg. 2007. Acidosis in feedlot cattle. Vet. Clin. Food Anim. 23:333-350.

Nagaraja, T. G. and E. C. Titgemeyer. 2007. Ruminal acidosis in beef cattle: the current microbiological and nutritional outlook. J. Dairy Sci. 90(E. Suppl.):E17-E38.

Nocek, J. E., W. P. Kautz, J. A. Z. Leedle, and J. G. Allman. 2002. Ruminal supplementation of direct-fed microbials on diurnal pH variation and in situ digestion in dairy cattle. J. Dairy Sci. 85:429-433.

NRC. 2000. Nutrient requirements of beef cattle. 7th rev. ed. Natl. Acad. Press, Washington, DC.

Overton, T. R. and M. R. Waldron. 2004. Nutritional management of transition dairy cows: strategies to optimize metabolic health. J. Dairy Sci. (E. Suppl) 87:E105-E119.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1997. The effect of grain source and grain processing on performance of feedlot cattle: a review. J. Anim. Sci. 75:868-879.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1998. Acidosis in cattle: a review. J. Anim. Sci. 76:275-286.

Owens, F. N., R. A. Zinn. 2005. Corn Grain for Cattle: Influence of Processing on Site and Extent of Digestion. Proc. Southwest Nutr. Conf.: 86-112

Owens, F. and S. Soderland. 2006. Ruminal and postruminal starch digestion by cattle. In: Proc. Cattle grain processing symposium, Stillwater, OK. p. 117-128

Phy, T. S. and F. D. Provenza. 1998. Eating barley too frequently or in excess decreases lambs' preference for barley but sodium bicarbonate and lasalocid attenuate the response. J. Anim. Sci. 76:1578-1583.

Prabhu, R., E. Altman, and M. A. Eiteman. 2012. Lactate and acrylate metabolism by *Megasphaera elsdenii* under batch and steady state conditions. Appl. Environ. Microbiol. 78(24):8564-8570.

Pritchard R. H. and K. W. Bruns. 2003. Controlling variation in feed intake through bunk management. J. Anim. Sci. 81:E133-E138.

RAGFAR. 2007. Ruminal acidosis-understandings, prevention and treatment. A review of veterinarians and nutritional professionals. Australian Veterinary Association: Qld.

Reinhardt, C. D., R. T. Brandt, Jr, K. C. Behnke, A. S. Freeman, and T. P. Eck. 1997. Effect of steam-flaked sorghum grain density on performance, mill production rate, and subacute acidosis in feedlot cattle. J. Anim. Sci. 75:2852-2857.

Rémond, D., J. I. Cabrera-Estrada, M. Champion, B. Chauveau, R. Coudure, and C. Poncet. 2004. Effect of corn particle size on site and extent of starch digestion in lactating dairy cows. J. Dairy. Sci. 87:1389-1399.

Rolfe, K., G. E. Erickson, T. J. Klopfenstein, and J. Vasconcelos. 2010. Effects of using wet distillers grains with solubles to adapt cattle to finishing diets on feed intake, ruminal pH, and ruminal hydrogen sulfide concentrations. Nebraska Beef Cattle Reports. p. 72-73.

Russell, J. B. and R. L. Baldwin. 1978. Substrate preferences in rumen bacteria: Evidence of catabolite regulatory mechanisms. Appl. Environ. Microbiol. 36(2):319-329.

Russell, J. B. and R. L. Baldwin. 1979. Comparison of substrate affinities among several rumen bacteria: a possible determinant of rumen bacterial competition. Appl. Environ. Microbiol. 37(3):531-536.

Russell J. B., W. M. Sharp, and R. L. Baldwin. 1979. The effect of pH on maximum bacterial growth rate and its possible role as a determinant of bacterial competition in the rumen. J. Anim. Sci. 48:251-255.

Russell, J. B. and T. Hino. 1985. Regulation of lactate production in *Streptococcus bovis*: A spiraling effect that contributes to ruminal acidosis. J. Dairy Sci. 68:1712-1721.

Russell, J. B. 1991. Intracellular pH of acid-tolerant ruminal bacteria. Appl. Environ. Microbiol. 57(11):3383-3384.

Schneider, C. J., A. L. Shreck, G. E. Erickson, and T. J. Klopfenstein. 2012. Effects of RAMP on feed intake and ruminal pH during adaptation to finishing diets. Nebraska Beef Cattle Report. p. 89-90.

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, D. J. Gibb, D. H. Crews, Jr., D. D. Hickman, M. Streeter, and T. A. McAllister. 2003. Effect of bunk management on feeding behavior, ruminal acidosis and performance of feedlot cattle: A review. J. Anim. Sci. 81:E149-158.

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, T. A. McAllister, D. J. Gibb, M. Streeter, and A. D. Kennedy. 2004. Effect of feed delivery fluctuations and feeding time on ruminal acidosis, growth performance, and feeding behavior of feedlot cattle. J. Anim. Sci. 82:3357-3365.

Scott T. L., C. T. Milton, G. E. Erickson, T. J. Klopfenstein, and R. A. Stock. 2003. Corn processing method in finishing diets containing wet corn gluten feed. J. Anim. Sci. 81:3182-3190.

Slyter, L. L. 1976. Influence of acidosis on rumen function. J. Anim. Sci. 43:910-929.

Soto-Navarro, S. A., C. R. Krehbiel, G. C. Duff, M. L. Galyean, M. S. Brown, and R. L. Steiner. 2000. Influence of feed intake fluctuation and frequency of feeding on nutrient digestion, digesta kinetics, and ruminal fermentation profiles in limit-fed steers. J. Anim. Sci. 78:2215-2222.

Stock R. A., M. H. Sindt, J. C. Parrott, and F. K. Goedeken. 1990. Effects of grain type, roughage level and monensin level on finishing cattle performance. J. Anim. Sci. 68:3441-3455.

Stokes, M. R. and L. S. Bull. 1986. Effect of sodium bicarbonate with three ratios of hay crop silage to concentrate for dairy cows. J. Dairy Sci. 69:2671-2680.

Suarez-Mena, F. X., G. I. Zanton, and A. J. Heinrichs. 2012. Effect of forage particle length on rumen fermentation, sorting and chewing activity of late-lactation and non-lactating dairy cows. The Animal Consortium 7:2 pp. 272-278.

Tajima, K., R. I. Aminov, T. Nagamine, H. Matsui, M. Nakamura, and Y. Benno. 2001. Diet-dependent shifts in the bacterial population of the rumen revealed with real-time PCR. Appl. Environ. Microbiol. 67:2766-2774.

Therion, J. J., A. Kistner, and J. H. Kornelius. 1982. Effect of pH on growth rates of rumen amylolytic and lactilytic bacteria. Appl. Environ. Microbiol. 44:428-434.

Vasconcelos, J. T., M. L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University Survey. J. Anim. Sci. 85:2772-2781.

Wallace, J. R. 1986. Catabolism of amino acids by *Megasphaera elsdenii* LC1. Appl. Environ. Microbiol. 51(5):1141-1143.

Wang, X., X. Li, C. Zhao, P. Hu, H. Chen, Z. Liu, G. Liu, and Z. Wang. 2012. Correlation between composition of the bacterial community and concentration of volatile fatty acids in the rumen during the transition period and ketosis in dairy cows. Appl. Environ. Microbiol. 78(7):2386-2392.

Wheelock, J. B., R. P. Rhoads, M. J. VanBaale, S. R. Sanders, and L. H. Baumgard. 2010. Effects of heat stress on energetic metabolism in lactating Holstein cows. J. Dairy. Sci. 93:644-655.

Yang, W. Z., K. A. Beauchemin, D. D. Vedres, G. R. Ghorbani, D. Colombatto, and D. P. Morgavi. 2004. Effects of direct-fed microbial supplementation on ruminal acidosis, digestibility, and bacterial protein synthesis in continuous culture. Anim. Feed. Sci. Technol. 114:179-193.

Yang, W. Z. and K. A. Beauchemin. 2007. Altering physically effective fiber intake through forage proportion and particle length: chewing and ruminal pH. J. Dairy. Sci. 90:2826-2838.

Young, B. A. 1981. Cold stress as it affects animal production. J. Anim. Sci. 52:154-163.

Young, B. A. 1983. Ruminant cold stress: effect on production. J. Anim. Sci. 57:1601-1607.

Zebeli, Q., S. J. Terrill, A. Mazzolari, S. M. Dunn, W. Z. Yang, and B. N. Ametaj. 2012. Intraruminal administration of *Megasphaera elsdenii* modulated rumen fermentation profile in mid-lactation dairy cows. J. Dairy Sci. 79:16-25.

Zinn, R. A. 1989. Influence of level and source of dietary fat on its comparative feeding value in finishing diets for feedlot steers: metabolism. J. Anim. Sci. 67:1038-1049.

Table 1-1. End products[1] produced by different strains of *Megasphaera elsdenii* when glucose or lactate were provided as a substrate

Strain of *M. elsdenii*	Substrate		Citation
	Glucose	Lactate	
B159	A, B, V	A, P, B, V	Forsberg, 1978
L8	B, C, F, V	A, P, B, V	Marounek et al., 1989
LC1	B, C, F, V	A, P, B, V	Marounek et al., 1989
J1	B, C, F, V	A, P, B, C	Marounek et al., 1989
AW106	A, B, C, F, V	A, P, B, V	Marounek et al., 1989
57	NA	A, P, B, V	Counotte et al., 1981
ATCC 17753	NA	A, P, B	Prabhu et al., 2012

[1]Acetate = A, butyrate = B, propionate = P, caproate = C, valerate = V, formate = F

Chapter 2 : Accelerated step-up regimes for feedlot heifers following oral dosing with Lactipro (*Megasphaera elsdenii*)[1]

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Abstract

A finishing study was conducted using crossbred heifers (n = 314; 385 ± 10.9 kg BW) to evaluate the potential for employing accelerated step-up regimes following oral dosing with *Megasphaera elsdenii* (Lactipro; MS-Biotec, Inc., Wamego, KS). Upon arrival at the feedlot cattle were given *ad libitum* access to alfalfa hay, and 36 h later were stratified by weight and randomly assigned to 54 pens (6 or 7 heifers/pen) within strata. Pens were randomly assigned to one of 5 step-up regimes that utilized between 1 and 5 diets. Diet 1=50% corn silage (CS) and 50% concentrate; 2=40% CS and 60% concentrate; 3=30% CS and 70% concentrate; 4=20% CS and 80% concentrate, and the final finishing diet (F) contained 10% CS and 90% concentrate. The control treatment (1234F; no Lactipro) consisted of feeding diets 1 through 4 for 5 d each prior to feeding F on d 21 and thereafter. Accelerated regimes consisted of a single oral dose (100 mL; 10^9 CFU/mL) of Lactipro administered at processing, followed by their respective diet regimes: 234F, 34F, 3F, 4F, and F. Diets 2 through 4 were fed 5 d each before progressing to the next diet in sequence. All diets were based on dry-rolled corn and modified wet corn distiller's grains. Linear and quadratic contrasts were analyzed for treatments 1234F, 234F, 34F, 4F, and F. Contrast between 1234F and the average of all accelerated regimes and an overall F-test were analyzed. During the first 30 d, accelerating the adaptation tended to decrease DMI (linear; P = 0.09) and decreased ADG (linear; $P < 0.01$) and efficiency (linear; $P < 0.01$). Over the entire 129 d study treatments did not differ with respect to DMI ($P \geq 0.12$) and ADG ($P \geq 0.25$) but, efficiency tended to be better ($P = 0.08$) for the 1234F group compared to the heifers on the accelerated regimens. Treatments did not differ with respect to liver abscess incidence or severity, HCW, dressing percentage, 12th rib fat thickness or, USDA quality grade ($P \geq 0.10$). Treatment impacted LM area (quadratic, $P < 0.01$), and it was smallest for carcasses from heifers

fed the 4F regimen. Marbling score generally increased with the accelerated step-up regimes (linear, P = 0.07) with the greatest improvement in carcasses of heifers placed directly onto the finishing diet. Heifers can be transitioned rapidly to high-concentrate diets following oral administration of *Megasphaera elsdenii* without compromising performance or carcass quality.

Diet adaptation, Lactipro, *Megasphaera elsdenii*

Introduction

Feedlots utilize highly fermentable carbohydrate sources to optimize cattle gains and efficiencies. Feeding highly fermentable feedstuffs without proper adaptation or in excess results in decreased ruminal pH due to accumulation of organic acids in the rumen, of which lactic acid is the primary contributor (Nagaraja and Lechtenberg, 2007). The accumulation of lactic acid is a result of a rapid proliferation of lactate-producing bacteria (*Streptococcus bovis*) coupled with a slow increase in lactate-utilizing bacteria (*Megasphaera elsdenii*; Mackie and Gilchrist, 1979). This, results in acidosis, a metabolic disorder which causes a decrease in ruminal pH, DMI, ADG, efficiency, and in severe cases can result in death. In addition, acidosis predisposes cattle to laminitis, polioencephalomalacia, and liver abscesses (Owens, 1998). Newly-arrived feedlot cattle are typically naïve to highly fermentable feedstuffs putting them at risk of acidosis; as a result they are transitioned to high-concentrate diets over a series of step-up diets where roughages are incrementally replaced by concentrates until the final diet has been achieved. These step-up diets are less energy dense than finishing diets and add additional labor in the feed mill, due to the mixing of multiple diets. Therefore, eliminating these inefficiencies by shortening or eliminating the adaptation period would improve feed mill production efficiency. Lactipro (MS-Biotec Inc., Wamego, KS) is a probiotic containing *Megasphaera elsdenii* NCIMB 41125, a lactate-utilizing bacterium. *Megasphaera elsdenii* is responsible for 60 to 95% of the lactate metabolism in the rumen (Counotte et al., 1981). The objective of this study was to evaluate the impact of an oral dose of *Megasphaera elsdenii* on heifer performance and carcass characteristics when accelerated step-up programs were utilized.

Materials and Methods

Procedures followed in this study were approved by the Kansas State University Institutional Animal Care and Use Committee. Three hundred and fourteen spayed crossbred heifers (385 ± 10.9 kg) were used in a randomized complete block study to evaluate the efficacy of *Megasphaera elsdenii* in accelerated step-up regimens. Upon arrival, heifers had access to alfalfa hay and water. Approximately 36 h after arrival heifers were vaccinated with Bovi-Shield Gold 4 (Pfizer Animal Health, Exton, PA), Vision 7 with Spur (Intervet Inc., Millsboro, DE), drenched with Safe-Guard (Intervet Inc., Millsboro, DE) dewormer, implanted with Revalor-IH (Intervet Inc., Millsboro, DE), weighed, and given a uniquely numbered ear tag. Heifers were stratified by BW and randomly assigned to 54 concrete-surfaced pens (36.5 m^2) containing 6 or 7 heifers each. Pens were then assigned to 1 of 5 step-up regimens, resulting in 9 replicates per treatment. Step-up regimens were: step 1, step 2, step 3, step 4, and finisher (1234F); step 2, step 3, step 4, and finisher (234F); step 3, step 4, and finisher (34F); step 3 and finisher (3F); step 4 and finisher (4F); and started directly on the finishing diet (F). All step-up diets were fed *ad libitum* for 5 d each, followed by the next diet in their respective regimen, until the finishing diet was reached and fed for the remainder of the study (Table 2-1). Heifers on accelerated step-up regimens (234F, 34F, 3F, 4F, and F) were orally dosed with a 100 mL of Lactipro, containing a minimum of $1×10^9$ CFU/mL of *Megasphaera elsdenii* strain NCIMB 41125, at initial processing. Following processing, cattle were immediately placed into their respective pens and fed their respective diets. Step-up diets and the finishing diet were based on dry rolled corn, modified wet corn distiller's grains, and corn silage (Table 2-2). Heifers were fed once daily and bunks were managed to contain approximately 0.23 to 0.45 kg of residual feed (DM basis) per heifer when fresh feed was delivered. When bunks were slick increases in feed deliveries were limited to 0.45 kg of feed (DM basis) per heifer. On d 59 heifers were re-implanted with Revalor-200 (Intervet Inc., Millsboro, DE) and received a pour-on insecticide (Ultra Boss; Intervet Inc., Millsboro, DE). Heifers were fed for 129 d, Zilmax (Intervet Inc., Millsboro; DE) was fed starting 23 d prior to harvest at 60 mg/heifer daily for 20 d, followed by a 3-d withdraw. Heifers were weighed immediately prior to being transported to a commercial abattoir where carcass data were collected. At the time of slaughter HCW and liver abscess scores were taken. Liver score data was collected using a scoring system of A- for 1 to 2 small abscesses (slight), A for 2 to 4 well organized abscesses (moderate), and A+ for one or more large abscesses with inflammation around the abscess (severe). Following a 24-h chill *longissimus* muscle area, 12th-rib subcutaneous fat thickness, KPH, marbling score, USDA quality grade, and USDA yield grade were obtained.

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS 9.1 (SAS Institute Inc., Cary, NC). Pen was the experimental unit and strata was the random effect. Contrast between 1234F and the average of all accelerated step-up regimens and an overall F-test were analyzed. Linear and quadratic contrasts of step-up regimens were used to compare 1234F, 234F, 34F, 4F, and F treatment differences.

Results and Discussion

Feedlot health and performance

Overall, health of cattle was excellent throughout the experiment. During the first week one heifer was treated for respiratory disease (34F), another was diagnosed and treated for possible coccidiosis (4F), and a third heifer was treated for infectious lameness (1234F). On d

119 of the experiment, a heifer on the 4F regimen was found dead in the pen, but gross necropsy revealed no obvious cause of death.

Feedlot performance is summarized in Table 2-3. During the first 30 d DMI was similar ($P > 0.90$) between heifers on the 1234F and the average of heifers on the accelerated regimens but, there was a tendency (linear, $P = 0.09$) for DMI to decrease from 10.3 to 10.1 kg/d as step-up regimens became more aggressive. Over the 129 d study DMI (12.15 ± 0.29 kg) was not impacted ($P \geq 0.29$) by step-up regimen. Daily DM feed deliveries are summarized in Fig. 2-1. There was no treatment × days interaction for daily DM feed deliveries ($P > 0.80$), but there was an effect of day ($P < 0.01$) and treatment ($P < 0.01$). During the first 30 d on feed ADG was greater ($P < 0.05$) for heifers on the 1234F compared to heifers on the 3F, 4F, and F and greater for heifers on the 234F compared to heifers on the 4F and F regimens ($P < 0.05$). Accelerating step-up regimen linearly decreased ADG ($P \leq 0.01$) and heifers on the 1234F regimen gained more than the average of heifers on the accelerated regimen during the first 30 d on feed ($P = 0.01$). Despite differences in ADG over the first 30 d on feed there were no differences in ADG over the 129 d study (P ≥ 0.20). Heifers on the 1234F regimen were more efficient ($P < 0.05$) than heifers on regimens 34F, 3F, 4F, and F, but efficiency was not different ($P > 0.05$) between heifers on the 1234F and 234F regimens or between heifers on the 234F, 34F, 3F, 4F, F regimens ($P > 0.05$) during the first 30 d. Over the entire 129 d study there was a tendency (P = 0.08) for heifers on the 1234F regimen to be more efficient than the average of heifers on the accelerated step-up regimens. Final shrunk BW was not different regardless of step-up regimen ($P \geq 0.18$).

In this study we did not place cattle on accelerated step-up regimens without administering *M. elsdenii* (Lactipro) at processing therefore, we cannot directly attribute any differences in performance or carcass characteristic to Lactipro. It has been reported in the literature that placing cattle onto high-concentrate diets without adaptation can severally depress intake, decrease ruminal pH, decrease blood pH, and compromise the health of the animal (Uhart and Carroll, 1967). Decreased performance has been reported for cattle adapted to high-concentrate diets in < 14 d (Brown et al., 2006).

A review by Brown et al. (2006) reported that adapting cattle to high concentrate diets in less than 14 d resulted in reduced performance if *ad libitum* access to the diet was allowed. The reduced performance observed when cattle are stepped up in < 14 d can likely be attributed to acidosis during the accelerated adaptation. Acidosis results in reduced DMI, performance, and reduction in nutrient absorbance (Owens et al., 1998). Burrin et al. (1988) stepped cattle up in either 14 or 7 d with varying levels of monensin and observed similar DMI over the first 28 d, but saw a decrease in ADG and feed efficiency when cattle were adapted in 7 d. Over the entire feeding period performance was not different between cattle adapted in 7 or 14 d. These results were similar to our results where intake tended to be decreased by accelerating diet adaptation and performance was decreased over the first 30 d but, was not affected over the entire study. Uhart and Carroll (1967) gave 8 steers previously fed an alfalfa hay diet *ad libitum* access to a 90% concentrate diet to induce acidosis. All steers except 1 stopped eating on d 2 or 3 of concentrate feeding, and did not began eating again for an additional 2 to 6 d. At the time steers stopped eating rumen pH was low and lactic acid was high. Dosing heifers with Lactipro and placing them directly onto finishing diets resulted in a decrease in DMI as opposed to cattle in the Uhart and Carroll (1967) study that were induced with acidosis by abruptly changing diets and formed a strong aversion to feed. In previous studies where cattle were inoculated with *Megasphaera elsdenii*, ruminal lactic acid accumulation and pH reduction were prevented during acidosis challenges (Klieve et al., 2003; Kung and Hession, 1995; McDaniel, 2009; Meissner et al., 2010). Other studies have shown an improvement in performance during the adaptation period when *M. elsdenii* was administered. When stepped-up from a 55% concentrate to a 94% concentrate diet over 16 d, steers dosed with *Megasphaera elsdenii* had greater DMI and ADG during the first 35 d than control steers (Henning et al., 2010). Control steers in the Henning et al. (2010) study were placed on a more aggressive step-up program than 1234F heifers in this study which put them at a greater risk of acidosis and may explain why administering *Megasphaera elsdenii* improved performance in their study. Krehbiel et al. (1995) observed reduced propionate absorption in lambs induced with acute acidosis 3 months after the acidosis challenge. Although many of the studies examining acidosis did not follow performance for extended periods, this study suggests that absorption and performance may be altered for 3 months following an acute acidosis challenge. Despite the lower performance during the step-up period, heifers dosed with Lactipro and placed on accelerated step-up regimens performed similar to heifers placed on a traditional step-up regimen, over the entire study. If acute acidosis had been a problem during the step-up period we may have observed decreased performance over the entire feeding period. The ability to accelerate adaptation without sacrificing performance was evident in our study as heifers dosed with Lactipro and given *ad libitum* access to diets that would be considered acidosis invoking, during the step-up period, maintained similar performance to heifers placed onto a traditional step-up regimen.

Carcass characteristics

Hot carcass weights, dressed yields, 12^{th} rib subcutaneous fat thickness, and KPH, were not different ($P \geq 0.10$), regardless of step-up regimen (Table 2-4). Step-up regimen had a quadratic effect on *longissimus* muscle area ($P < 0.01$) with carcasses from heifers on the 4F step-up regimen having the smallest *longissimus* muscle area. *Longissimus* muscle area was not different ($P > 0.10$) between carcasses from heifers on the 1234F regimen and carcasses from heifers on the accelerated regimens. Incidence and severity of liver abscesses were not impacted by step-up regimen ($P \geq 0.15$; Table 2-5). Average YG was not different ($P \geq 0.23$) regardless of step-up regimen; however, there was a quadratic effect (P = 0.04) on the percentage of YG 1 carcasses with cattle on the 234F step-up regimen having the lowest percentage of YG 1 carcasses. The percentage of YG 2 carcasses tended to be higher in the 4F group (quadratic, P = 0.06; Table 2-6). There was a trend (linear, $P = 0.07$) for increased marbling as step-up regimen was accelerated with carcasses from the F group having the most marbling (Table 2-7). There were no differences in quality grade ($P > 0.10$) regardless of step-up regimen.

Liver abscesses have been associated with acidosis (Nagaraja and Chengappa, 1998). Decreased HCW and dressed yields have been observed in carcasses that contain abscessed livers (Brink et al., 1990; Brown and Lawrence, 2010). Parsons et al. (2010) stepped cattle up in 21 d or 10 d and observed a tendency for an increase in liver abscess when cattle were stepped up in 10 d. Despite the more aggressive step-up regimens incidence of liver abscess, HCW, and dressed yields were not affected by step-up regimen. Marbling or intramuscular fat is a key component in determining beef quality grade. The feeding of high-concentrate diets increases marbling compared to feeding high-roughage diets (Crouse et al., 1984). Glucose is the main carbon source used in the deposition of intramuscular fat, whereas subcutaneous fat deposition uses predominantly acetate and lactate as its carbon sources (Hausman et al., 2009). Feeding of high-concentrate diets decreases the acetate:propionate ratio, increasing propionate available for gluconeogenesis and potentially intramuscular fat deposition. In addition, increasing the number of days a high-concentrate diet is fed increases marbling score until the genetic potential of the animal to deposit intramuscular fat is reached, at which time it plateaus or decreases (May et al., 1992; Duckett et al., 1993). The trend seen in our study for improved marbling when heifers were dosed with Lactipro and diet adaptation was accelerated may be a result of the increased number of days a high-concentrate diet was fed.

Implications

Heifers drenched with Lactipro at initial processing can be placed on accelerated step-up regimens without negatively impacting performance and maintaining or improving carcass quality. This allows for simplification of feed mill operations by decreasing the number of diets required to finish cattle.

Literature Cited

Brink, D. R., S. R. Lowry, R. A. Stock, and J. C. Parrott. 1990. Severity of liver abscesses and efficiency of feed utilization of feedlot cattle. J. Anim. Sci. 68:1201-1207

Brown, T. R. and T. E. Lawrence. 2010. Association of liver abnormalities with carcass grading performance and value. J. Anim. Sci. 88:4037-4043.

Brown, M. S., C. H. Ponce and R. Pulikanti. 2006. Adaptation of beef cattle to high-concentrate diets: Performance and ruminal metabolism. J. Anim. Sci. 84:E25.

Burrin, D. G., R. A. Stock, and R. A. Britton. 1988. Monensin level during grain adaptation and finishing performance in cattle. J. Anim. Sci. 66:513-521.

Counotte, G. H. M., R. A. Prins, R. H. A. M. Janssen, and M. J. A. Debie. 1981. Role of *Megasphaera elsdenii* in the fermentation of [2-^{13}C] DL-lactate in the rumen of dairy cattle. App. Environ. Microbiol. 42:649-655.

Crouse, J. D., H. R. Cross, and S. C. Seideman. 1984. Effects of a grass or grain diet on quality of three beef muscles. J. Anim. Sci. 58:619-625.

Duckett, S. K., D. G. Wagner, L. D. Yates, H. G. Dolezal, and S. G. May. 1993. Effects of time on feed on beef nutrient composition. J. Anim. Sci. 71:2079-2088.

Henning, P. H., C. H. Horn, K.-J. Leeuw, H. H. Meissner, and F. M. Hagg. 2010. Effect of ruminal administration of the lactate-utilizing strain *Megasphaera elsdenii* (ME) NCIMB 41125 on abrupt or gradual transition from forage to concentrate diets. Anim. Feed Sci. Technol. 157:20-29.

Hausman, G. J., M. V. Dodson, K. Ajuwon, M. Azain, K. M. Barnes, L. L. Guan, Z. Jiang, S. P. Poulos, R. D. Sainz, S. Smith, M. Spuclock, J. Novakofski, M. E. Fernyhough, and W. G. Bergen. 2009. Board-Invited Review: The biology and regulation of preadipocytes and adipocytes in meat animals. J. Anim. Sci. 87:1218-1246.

Klieve, A. V., D. Hennessy, D. Ouwerkerk, R. J. Forster, R. I. Mackie, and G. T. Attwood. 2003. Establishing populations of *Megasphaera elsdenii* YE 34 and *Butyrivibrio fibrisolvens* YE 44 in the rumen of cattle fed high grain diets. J. Appl. Microbiol. 95:621-630.

Krehbiel, C. R., R. A. Britton, D. L. Harmon, T. J. Wester and R. A. Stock. 1995. The effects of ruminal acidosis on volatile fatty acid absorption and plasma activities of pancreatic enzymes in lambs. J. Anim. Sci. 73:3111-3121.

Kung, L. Jr and A. O. Hession. 1995. Preventing *in vitro* lactate accumulation in ruminal fermentations by inoculation with *Megasphaera elsdenii*. J. Anim. Sci. 73:250-256.

Mackie, R. I. and Frances M. C. Gilchrist. 1979. Changes in lactate-producing and lactate-utilizing bacteria in relation to pH in the rumen of sheep during stepwise adaptation to a high-concentrate diet. Appl. and Environ. Microbiol. p. 422-430.

May, S. G., H. G. Dolezal, D. R. Gill, F. K. Ray, and D. S. Buchanan. 1992. Effect of days fed, carcass grade traits, and subcutaneous fat removal on postmortem muscle characteristics and beef palatability. J. Anim. Sci. 70:444-453.

McDaniel, M. R. 2009. The effects of dosing feedlot cattle with *Megasphaera elsdenii* strain NCIMB 41125 prior to the introduction of a grain-rich diet. MS Thesis. Kansas State Univ., Manhattan.

Meissner, H. H., P. H. Henning, C. H. Horn, K-J. Leeuw, F. M. Hagg, and G. Fouché. 2010. Ruminal acidosis: A review with detailed reference to the controlling agent *Megasphaera elsdenii* NCIMB 41125. S. Afr. J. Anim. Sci. 40:79-100.

Nagaraja, T. G. and K. F. Lechtenberg. 2007. Acidosis in feedlot cattle. Vet. Clin. Food Anim. 23:333-350.

Nagaraja, T. G. and M. M. Chengappa. 1998. Liver abscesses in feedlot cattle: a review. J. Anim. Sci. 76:287-298.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1998. Acidosis in cattle: a review. J. Aim. Sci. 76:275-286.

Parsons, G. L., C. E. Walker, K. A. Miller, L. K. Thompson, J. J. Higgins, and J. S. Drouillard. 2010. Effects of monensin concentration and accelerated step-up regimens on performance and carcass trait. Plains Nutrition Council Spring Conference, San Antonio, TX. P. 112-113 (Abstr.)

Uhart, B. A. and F. D. Carroll. 1967. Acidosis in beef steers. J. Anim. Sci. 29:1195.

Table 2-1. Step-up regimens

	Step-up regimen				
DOF	1234F	234F	34F	4F	F
1-5	Step 1	Step 2	Step 3	Step 4	Finisher
6-10	Step 2	Step 3	Step 4	Finisher	Finisher
11-15	Step 3	Step 4	Finisher	Finisher	Finisher
16-20	Step 4	Finisher	Finisher	Finisher	Finisher
21-129	Finisher	Finisher	Finisher	Finisher	Finisher

Table 2-2. Diet composition DM basis

Ingredient	Step-up Diets (% DM) Step 1	Step 2	Step 3	Step 4	Finisher
Dry rolled corn	5.69	15.69	25.69	35.69	45.69
Modified wet corn distiller's grains	40.00	40.00	40.00	40.00	40.00
Corn silage	50.00	40.00	30.00	20.00	10.00
Supplement[a]	2.14	2.14	2.14	2.14	2.16
Feed additive[b]	2.16	2.16	2.16	2.16	2.16
Nutrient analyses					
DM	48.41	52.21	56.66	61.93	68.28
CP	15.88	15.97	16.06	16.15	16.24
NDF	38.07	33.87	29.67	25.47	21.27
Crude fat	6.62	6.74	6.86	6.98	7.10
Calcium	0.78	0.76	0.74	0.72	0.70
Phosphorus	0.46	0.47	0.48	0.48	0.49
Potassium	0.94	0.88	0.82	0.76	0.70

[a]Formulated to provide the following per kilogram of dietary DM: 0.1 mg of Co; 1.0 mg of Cu; 0.6 mg I; 60 mg of Mn; 0.25 mg Se; 60 mg Zn; 2,200 IU of vitamin A; and 20 IU of vitamin E per kg of DM.

[b]Fed at 0.23 kg/d to provide 300 mg monensin (Elanco Animal Health, Indianapolis, IN) and 90 mg of tylosin (Elanco Animal Health) daily.

Table 2-3Feedlot performance of heifers dosed with *M. elsdenii* at processing and placed on accelerated step-up regimens

	Step-up regimen								Contrast, P-value		
Item	1234F	234F	34F	3F	4F	F	SEM	F-test[a]	Cont vs Lact[b]	Lin[c]	Quad[d]
Number	63	63	63	63	62	63					
Days on feed	129	129	129	129	129	129					
Initial BW, kg	385	385	385	384	384	386	10.9	0.28	0.60	0.96	0.12
d 1-30											
DMI, kg/d	10.34	10.69	10.30	10.41	10.21	10.11	0.36	0.20	0.98	0.09	0.37
ADG, kg/d	1.89[f]	1.80[fg]	1.71[fgh]	1.61[gh]	1.59[h]	1.59[h]	0.079	0.02	0.01	< 0.01	0.58
G:F, kg/kg	0.1845[f]	0.1690[fg]	0.1666[g]	0.1548[g]	0.1571[g]	0.1576[g]	0.0081	< 0.01	< 0.01	< 0.01	0.26
d 1-129											
Final BW, kg[e]	600	596	593	588	594	597	11.8	0.48	0.18	0.51	0.18
DMI, kg/d	12.18	12.33	12.15	12.18	12.00	12.11	0.31	0.74	0.87	0.29	0.88
ADG, kg/d	1.66	1.63	1.61	1.58	1.63	1.64	0.03	0.52	0.20	0.52	0.26
G:F, kg/kg	0.1372	0.1329	0.1330	0.1297	0.1358	0.1357	0.0036	0.08	0.08	0.98	0.11

[a]Overall F-test
[b]1234F vs accelerated step-up regimens receiving Lactipro
[c]Linear effect of step-up regimens 1234F, 234F, 34F, 4F, and F
[d]Quadratic effect of step-up regimens 1234F, 234F, 34F, 4F, and F
[e]Final BW shrunk (4%)
[fgh]Within a row, means without a common superscript differ ($P \leq 0.05$)

Table 2-4. Carcass characteristics of heifers dosed with *M. elsdenii* at processing and placed on accelerated step-up regimens

	Step-up regimen								Contrast, P-value		
Item	1234F	234F	34F	3F	4F	F	SEM	F-test[a]	Cont vs Lact[b]	Lin[c]	Qaud[d]
HCW, kg	380	378	378	375	377	380	7.9	0.78	0.46	0.87	0.38
Dress Yield, %	63.41	63.48	63.77	63.68	63.34	63.70	0.28	0.78	0.49	0.60	0.88
LM area, cm^2	91.47	89.20	88.78	89.73	88.37	92.46	1.47	0.10	0.18	0.76	< 0.01
KPH, %	2.47	2.52	2.50	2.42	2.46	2.50	0.06	0.81	0.86	0.94	0.88
Subcutaneous fat thickness,12^{th}-rib, cm	1.13	1.16	1.02	1.12	0.96	1.10	0.06	0.10	0.36	0.14	0.11

[a]Overall F-test

[b]1234F vs accelerated step-up regimens receiving Lactipro

[c]Linear effect of step-up regimens 1234F, 234F, 34F, 4F, and F

[d]Quadratic effect of step-up regimens 1234F, 234F, 34F, 4F, and F

[efg]Within a row, means without a common superscript differ ($P \leq 0.05$)

Table 2-5. Incidence and severity of liver abscesses in carcasses from heifers dosed with *M. elsdenii* and placed onto accelerated step-up regimens.

	Step-up regimen								Contrast, *P*-value		
Item	1234F	234F	34F	3F	4F	F	SEM	F-test[a]	Cont vs Lact[b]	Lin[c]	Quad[d]
Liver abscess, %	15.87	22.22	7.94	11.11	8.03	14.29	4.39	0.15	0.50	0.20	0.38
Abscess severity, %[e]											
A-	6.35	6.35	0.00	3.18	3.22	3.17	2.47	0.41	0.22	0.21	0.29
A	1.59	7.94	3.17	3.17	0.00	6.35	2.44	0.17	0.23	0.83	0.86
A+	7.94	7.94	4.76	4.76	4.82	4.76	3.03	0.91	0.43	0.32	0.78

[a]Overall F-test
[b]1234F vs accelerated step-up regimens receiving Lactipro
[c]Linear effect of step-up regimens 1234F, 234F, 34F, 4F, and F
[d]Quadratic effect of step-up regimens 1234F, 234F, 34F, 4F, and F
[e]Liver abscess scores of A-, A, and A+ represent slight, moderate, or severe abscesses, respectively

Table 2-6. USDA yield grades of carcasses from heifers dosed with *M. elsdenii* and placed onto accelerated step-up regimens

	Step-up regimen								Contrast, *P*-value		
Item	1234F	234F	34F	3F	4F	F	SEM	F-test[a]	Cont vs Lact[b]	Lin[c]	Quad[d]
YG	2.35	2.48	2.37	2.35	2.19	2.30	0.11	0.51	0.92	0.23	0.79
YG 1, %	15.87	6.35	11.11	14.29	11.26	20.63	4.57	0.25	0.50	0.28	0.04
YG 2, %	42.59	44.44	50.79	46.03	59.68	38.10	6.28	0.22	0.48	0.77	0.06
YG 3, %	31.75	44.44	28.57	30.16	27.42	31.75	5.90	0.36	0.91	0.36	0.93
YG 4, %	9.52	4.76	9.52	9.52	1.61	9.52	3.43	0.38	0.49	0.76	0.29

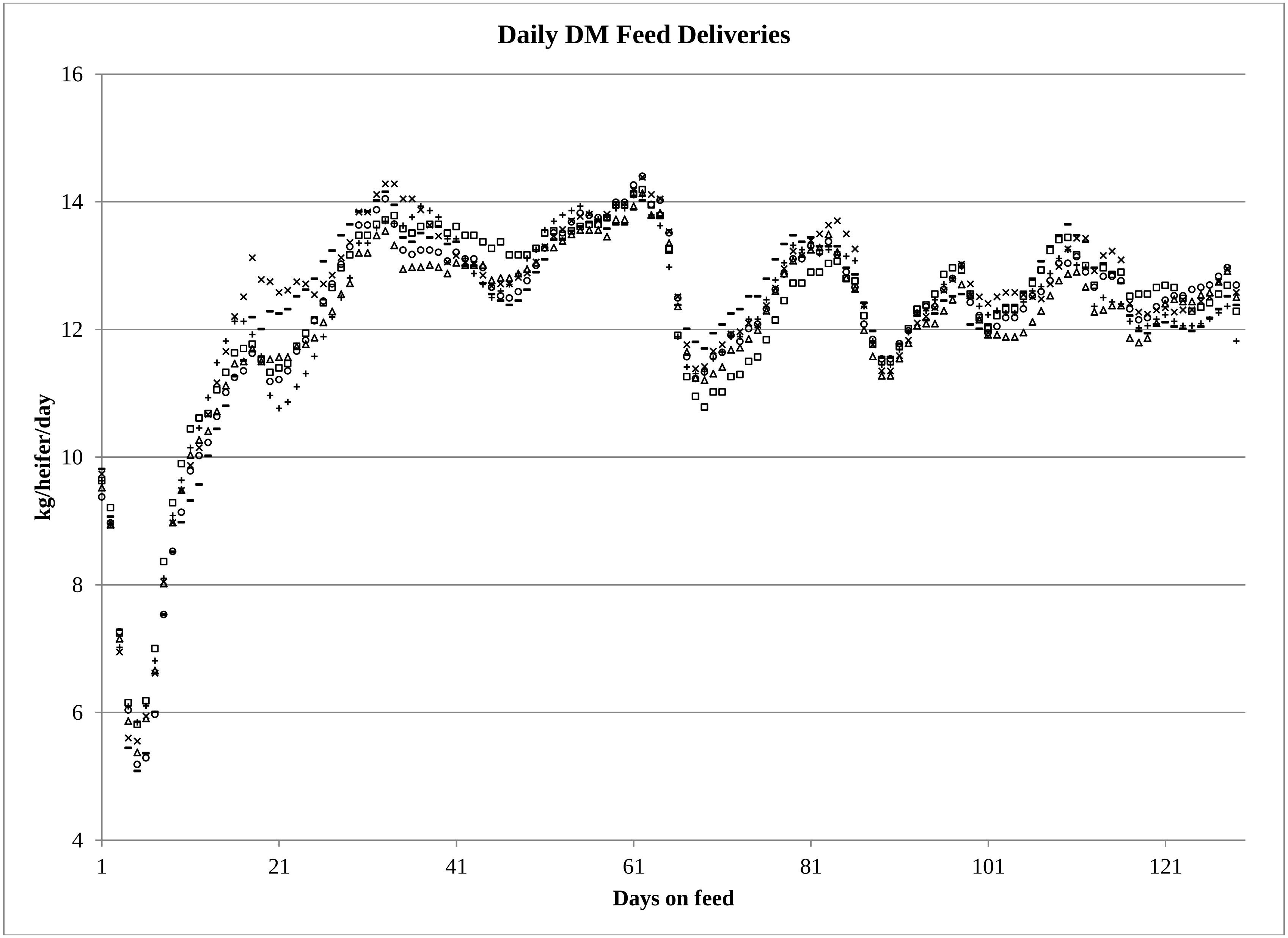
[a]Overall F-test
[b]1234F vs accelerated step-up regimens receiving Lactipro
[c]Linear effect of step-up regimens 1234F, 234F, 34F, 4F, and F
[d]Quadratic effect of step-up regimens 1234F, 234F, 34F, 4F, and F

Table 2-7. Marbling and USDA quality grade of carcasses from heifers dosed with *M. elsdenii* and placed on to accelerated step-up regimens

	Step-up regimen								Contrast, *P*-value		
Item	1234F	234F	34F	3F	4F	F	SEM	F-test[a]	Cont vs Lact[b]	Lin[c]	Quad[d]
Marbling[e]	467	467	466	449	471	497	10.9	0.07	0.82	0.07	0.16
Prime, %	0.00	3.17	0.00	0.00	3.23	3.17	1.58	0.30	0.27	0.24	0.99
Choice, %	68.25	71.43	73.02	65.08	70.98	71.43	5.85	0.94	0.74	0.75	0.67
Premium choice, %	12.70	11.11	9.52	14.29	17.75	17.46	4.44	0.71	0.78	0.24	0.45
Select, %	26.98	17.46	15.87	28.57	17.71	15.87	5.27	0.26	0.16	0.16	0.30
NoRoll, %[f]	0.00	0.00	1.59	0.00	0.00	0.00	0.65	0.42	0.65	1.00	0.23
B-maturity, %	3.17	6.35	6.35	6.35	8.06	6.35	3.03	0.93	0.29	0.40	0.48
Other, %[g]	1.59	1.59	3.17	0.00	0.00	3.17	1.64	0.54	1.0	0.77	0.80

[a]Overall F-test
[b]1234F vs accelerated step-up regimens receiving Lactipro
[c]Linear effect of step-up regimens 1234F, 234F, 34F, 4F, and F
[d]Quadratic effect of step-up regimens 1234F, 234F, 34F, 4F, and F
[e]Marbling score 400-499 = small
[f]Low quality carcasses that were not assigned a USDA quality grade
[g]Other includes dark cutters, heiferettes, and commercials

Figure 2-1. Daily dry matter feed deliveries of heifers dosed with *M. elsdenii* at processing and placed on accelerated ration step-up regimens
(– 1234F, × 234F, + 34F, □ 3F, Δ 4F, and ○ F; SEM = 0.40; treatment $P < 0.01$; days on feed $P < 0.01$; treatment × days on feed $P > 0.80$).



Daily DM Feed Deliveries
16
14
12
10
8
6
4
kg/heifer/day
1
21
41
61
81
101
121
Days on feed

Chapter 3 **: Dosing steers orally with Lactipro (*Megasphaera elsdenii* strain NCIMB 41125) to decrease roughage required during the finishing period**[1]

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Abstract

Two experiments were conducted to evaluate the efficacy of dosing steers with Lactipro and placing them directly onto a finishing diet to decrease the quantity of roughage fed during finishing. In the first experiment, 443 steers (BW 401 ± 2.44 kg) were placed on a traditional step-up regimen consisting of 3 step-up diets fed for 6 d each (Control), or were given a 100-mL oral dose of Lactipro at processing and placed directly onto a finishing diet (Lactipro). All diets were based on steam-flaked corn, wet corn gluten feed, and corn silage (CS). The step 1 diet contained 40% CS, step 2: 30% CS, step 3: 20% CS and the finishing diet contained 10% CS. Lactipro steers tended to have less ($P = 0.07$) DMI compared to Control steers. Placing steers directly onto the finishing diet decreased silage consumption by 17% ($P < 0.01$) over the 115-d feeding period. Treatment did not affect ADG ($P = 0.65$) or efficiency ($P = 0.14$). Dressed yield, HCW, LM area, KPH, 12th-rib fat, liver abscesses, marbling score, and yield grade were unaffected by treatment ($P \geq 0.19$). Dosing steers with Lactipro and placing them directly onto the finishing diet tended to increase the percentage of Choice ($P = 0.07$) and decreased the percentage of Select ($P = 0.06$) carcasses compared to the Control. In the Exp. 2, 90 steers (BW 399 ± 2.31 kg) from Exp. 1 were utilized to measure apparent total tract digestibility during the 24-d step-up period, utilizing the same treatments as Exp. 1. Total pen fecal collections were taken daily and composited into 6-d periods corresponding with each phase of the control step-up regimen followed by a 6-d period on the final finishing diet. Control steers had greater DMI ($P < 0.01$) and DM fecal output ($P < 0.01$) during the step-up period compared to Lactipro steers. Dry matter digestibility was not different ($P = 0.11$) over the entire 24-d study. Placing steers directly onto the finishing diet resulted in greater apparent CP digestibility ($P = 0.05$) and poorer apparent NDF digestibility ($P < 0.01$) over the 24-d step-up period compared to Control steers.

Starch digestibility was not impacted by treatment ($P \geq 0.26$). Dosing steers with Lactipro and placing them directly on feed is a viable option for decreasing the quantity of roughage fed during the finishing period.

Lactipro, roughage, diet adaptation, digestibility

Introduction

Roughages are utilized in feedlot diets to reduce the risk of digestive disturbances, thus maintaining rumen health and function. During the step-up period cattle are gradually transitioned from high-roughage diets to high-concentrate diets. The step-up period, although important, is logistically challenging as multiple diets must be manufactured to accommodate animals at various stages of the transition period. Additionally, step-up diets are less energy dense than finishing diets due to their increased roughage content. Roughages present complications in the feed mill due to low bulk density and poor flow characteristics, which makes them difficult to handle and mix (Britton and Stock, 1986). Roughages are predisposed to high shrink losses and low bulk density decreases load capacities of mixers and delivery vehicles, increasing the number of trips that must be made to deliver the same mass of feed. Due to their lower digestibility, forages are relatively expensive on an energy basis relative to other feedstuffs in typical feedlot diets. Drought conditions, which are prevalent across the United States at present, resulted in decreased availability and higher cost for roughages. Despite these disadvantages, gradual adaptation to concentrate based diets is deemed essential for achieving optimal performance (Brown et al., 2006). If cattle are not properly adapted to concentrate-based diets an unstable shift in ruminal microflora can result in accumulation of VFA and lactic acid, resulting in acidosis (Owens, 1998). Acidosis decreases performance and predisposes cattle to bloat, liver abscesses, laminitis, and polioencephalomalacia (RAGFAR, 2007). Lactipro is a probiotic containing *Megasphaera elsdenii*, a lactate-utilizing bacterium that effectively prevents lactic acid accumulation during acidosis challenges (Klieve et al., 2003; Kung and Hession, 1995; McDaniel, 2009). The objective of our study was to determine if steers dosed with Lactipro at processing could be placed directly onto finishing diets, thereby reducing the quantity of roughage required during finishing and determine the effect of eliminating the step-up period on apparent total tract digestibility during the first 24 d on feed.

Materials and Methods

Experiment 1

Care and handling of animals used in this study were conducted under the approval of the Kansas State University Institutional Animal Care and Use Committee. Four hundred and forty-three crossbred steers (initial BW 401 ± 2.44) were utilized in a randomized complete block design to determine if steers given Lactipro at initial processing could be placed directly onto finishing diets reducing the quantity of roughage required during the finishing period. Upon arrival, steers were fed brome hay. Steers were processed approximately 24 h after arrival. At processing, steers were weighed, given uniquely numbered ear tags, vaccinated against common viral (Bovi-Shield Gold 5; Pfizer Animal Health, Exton, PA) and clostridial (Ultra bac 7 Somubac; Pfizer Animal Health, Exton, PA) diseases, treated for internal and external parasites (Dectomax; Pfizer Animal Health, Exton, PA), and implanted with Revalor-XS (Intervet Inc., Millsboro, DE). Half of the steers were assigned to a traditional step-up program (Control) consisting of 3 step-up diets fed for 6 d each, followed by a finishing diet, which was fed for the remainder of the study. The remaining steers were orally dosed with 100-mL of Lactipro (MS-Biotec, Inc., Wamego, KS) at processing and placed directly onto a finishing diet (Lactipro;

Table 3-1). Steers were assigned to treatments based on order through the chute at processing and sorted into 24 pens with 14 or 15 steers/pen and 12 pens with 7 or 8 steers/pen, resulting in 18 replicates per treatment. Diets were based on steam-flaked corn, wet corn gluten feed, and corn silage (Table 3-2). Steers were fed their respective diets once daily for 115 d. Bunks were managed to provide *ad libitum* access to the diets, though increases in daily feed deliveries were limited to 0.45 kg (dry basis) per steer. Steers were weighed immediately prior to being transported to a commercial abattoir and at the time of slaughter HCW and liver score data were collected. Liver score data was collected using a scoring system of A- for 1 to 2 small abscesses (slight), A for 2 to 4 well organized abscesses (moderate), and A+ for one or more large abscesses with inflammation around the abscess (severe). Following a 24 h chill, USDA yield and quality grades; 12^{th} rib fat thickness; percent kidney, pelvic, and heart fat; *longissimus* muscle area; and marbling score were recorded.

Statistical analysis

Statistical analyses were performed using the MIXED procedure of SAS 9.1 (SAS Institute Inc., Cary, NC). Pen was the experimental unit, treatment was the fixed effect, and block was the random variable.

Experiment 2

Care and handling of animals used in this study were conducted under the approval of the Kansas State University Institutional Animal Care and Use Committee. A group of 90 crossbred steers (BW 399 ± 2.31 kg) from Exp. 1 were used in a 24-d study to determine the impact of step-up regimen on apparent total tract digestibilities of DM, CP, NDF, starch, and phosphorous. Receiving and processing procedures were the same as Exp. 1. Steers were sorted based on order through the chute, resulting in 12 pens with 7 or 8 steers/pen to provide 6 replicates per treatment. Treatments were 1) traditional step-up program (Control) consisting of 3 step-up diets fed for 6 d each and the finishing diet for the remainder of the study (Table 3-2) and 2) orally dosed with 100 mL of Lactipro at processing and placed directly onto the finishing diet (Lactipro). Step-up diets and finishing diets were the same as in Exp. 1 (Table 3-1). Steers were housed in concrete-surfaced pens (36 m^2) with an empty pen between each pen of steers to prevent mixing of feces between pens. Before placing steers into their respective pens, the surface of all pens were thoroughly cleaned. Apparent total tract digestibilities were measured during each of four 6-d periods corresponding with the different diets fed to the Control steers.

Fecal collection

Total fecal output from each pen of steers was measured daily at 1200 h, immediately prior to feeding. Steers were moved from their home pen to an empty pen, feces were collected in large plastic containers, weighed, homogenized, and sub-sampled. Samples were dried at 55° C in a forced-air oven for 48 h until all moisture was removed and sample weight was stable. Weighted daily samples from each pen were composited for each period and ground through a 1-mm screen. This resulted in one sample per pen for days 1-6, 7-12, 13-18, and 19-24. Samples were analyzed for Starch, NDF, CP, and P. Starch was determined using the procedure of Herrera-Saldana and Huber (1989) using a Technicon Autoanalyzer II to measure free glucose (Gochman and Schmitz, 1972). Neutral detergent fiber was determined using an Ankom 200 Fiber Analyzer (Ankom Technologies, Macedon, NY) by the procedure described by Van Soest et al. (1991). The AOAC (1995) official method 990.03 was used for determination of CP by measuring N content using a N analyzer (FP-2000, Leco Corp., St. Joseph, MI). Phosphorous was determined by the procedure described by Fiske and Subbarow (1925) where absorbance was read at 660 nm.

Feed and orts

Residual feed was removed from feed bunks daily at the time of fecal collection, weighed, homogenized, and sub-sampled. Diet samples were collected daily, and samples of diets and orts were dried for 48 h in a forced-air oven at 55° C. Diet and residual feed samples were used to calculate daily DM feed intakes. Following drying, samples were analyzed for Starch, NDF, CP, and P using the methods described previously.

Statistical analysis

Data were analyzed using the MIXED procedure in SAS 9.1 (SAS Institute Inc., Cary, NC). Pen was the experimental unit and the model statement included treatment, period, and the treatment × period interaction. Block was the random variable.

Results and Discussion

Exp. 1 cattle health

A steer in the Lactipro group died on d 19. Gross necropsy reported necrotizing fasciitis and cellulitis (bacterial infection) as the cause of death. Another steer in the Lactipro group was euthanized on day 49 due to infectious lameness. High incidence of foot rot (8.4%) was observed in both treatment groups.

Exp. 1 feedlot performance

In our study we did not have a negative control to directly compare steers placed directly onto finishing diets with or without Lactipro. However, previous research has demonstrated that cattle placed directly onto a finishing diet can experience severely depressed intake, decreased ruminal and blood pH, and compromised health (Uhart and Carroll, 1967).

Steer performance in this study is summarized in Table 3-3. Initial (*P* = 0.12) and final (*P* = 0.21) BW were not different between treatments. Steers placed on the traditional step-up program tended (*P* = 0.07) to have greater DMI and consumed 17% more roughage (*P* < 0.001) during the finishing period than Lactipro steers. Roughage consumed during the 18-d step-up period accounted for 24 and 9% of the total roughage consumed during the feeding period for Control and Lactipro steers, respectively. There was a day × treatment interaction (*P* < 0.01) for DM feed deliveries (Fig. 3-1) where deliveries were greater for Control steers (*P* < 0.01) on d 4 to 18 compared to Lactipro steers but not different after d 18, suggesting that the tendency for reduced intakes seen in Lactipro steer was largely due to the first 18 d on feed. Dry matter feed deliveries increased over time (*P* < 0.01) for both treatments. Average daily gain (*P* = 0.65) and gain efficiency (*P* = 0.14) were similar for steers gradually adapted to the finishing diet and steers placed directly onto finishing diets.

An abrupt change from forage diets to high-concentrate diets can induce acidosis. Allison et al. (1964) fed cracked wheat to sheep that previously had been fed diets of alfalfa pellets; alfalfa pellets plus 700 g cracked wheat; or alfalfa pellets plus ruminal fluid transferred from sheep fed alfalfa pellets plus 700 g cracked wheat prior to the challenge. Sheep previously adapted to wheat or inoculated with rumen fluid from a sheep adapted to wheat did not experience acidosis when the diet was changed abruptly, but the sheep given only alfalfa pellets had reduced ruminal pH, increased ruminal lactate, loss of appetite, and reduced rumen motility. Steers naïve to concentrates were given *ad libitum* access to a high-concentrate diet and all steers except 1 stopped eating within 2-to-3 d, at which time ruminal pH was below 5 and lactate concentrations were approximately 100 mM (Uhart and Carroll, 1967). Dosing of *Megasphaera elsdenii* to cattle helps prevent lactic acid accumulation following a grain challenge, allowing for more aggressive feeding practices (Henning et al., 2010). During abrupt changes from forage-based diets to concentrate-based diets, cattle given *Megasphaera elsdenii* maintained higher rumen pH and DMI compared to cattle not dosed with *Megasphaera elsdenii* (Robinson et al., 1992). McDaniel (2009) monitored ruminal pH in cattle following an abrupt switch from a forage- to a grain-based diet and observed higher ruminal pH and lower ruminal lactate concentrations in steers dosed with *M. elsdenii* compared to controls. No signs of acute acidosis were observed in this study when steers were dosed with Lactipro and placed directly onto a finishing diet, but cattle in the Lactipro treatment tended to eat less DM ($P = 0.07$). This tendency for reduced intake may be attributed to differences during the first 18 d on feed (Fig. 3-1) after which time both treatments were on the finishing diet and feed deliveries were similar between treatments. There could be several explanations for the trend of reduced DMI in steers placed directly onto finishing diets. Even when lactic acid accumulation is prevented subacute acidosis can occur as a result of providing readily fermentable substrate to the ruminal microflora, increasing VFA production (Nagaraja and Lechtenberg, 2007). In a review of diet adaptation, Brown et al. (2006) concluded that performance and DMI is generally reduced when cattle are adapted to high concentrate diets in ≤ 14 d. Regardless of the tendency for reduced DMI in Lactipro steers performance was not negatively impacted.

Exp 1. carcass traits

Carcass characteristics are summarized in Tables 3-4 to 3-6. Treatment did not affect HCW; dressed yield; *longissimus* muscle area; kidney, pelvic, and heart fat; incidence of liver abscess or severity; marbling score or 12th-rib fat thickness ($P \geq 0.19$). Average USDA yield grade was not significantly different ($P = 0.82$) between treatment groups. There was a tendency ($P = 0.10$) for a greater percentage of YG 1 carcasses in the Control group compared to the

Lactipro group, but there were no differences ($P \geq 0.15$) in the percentage of YG 2, 3, 4, or 5 carcasses between treatments (Table 3-5). There were no differences in the percentage of carcasses grading Prime, premium Choice, B-maturity, or carcasses that did not grade ($P > 0.14$). The percentage of carcasses grading Choice tended ($P = 0.07$) to be greater for the Lactipro group, and the percentage of carcasses grading Select tended ($P = 0.06$) to be greater for the Control group (Table 3-6).

Liver abscesses are often associated with acidosis (Brent, 1976; Nagaraja and Chengappa, 1998). Cattle with severe liver abscesses at harvest can have reduced DMI, ADG, and poor feed efficiency during finishing (Brink et al., 1990). In our study, ADG and efficiency were not compromised by starting steers on a finishing diet, suggesting that acidosis was not a problem during the finishing period. Furthermore, there were no differences in incidence or severity of liver abscesses between treatments. Steers dosed with Lactipro were fed the finishing diet 18 d longer than control steers, which may explain the trend for fewer YG 1 carcasses ($P = 0.01$) and more carcasses grading Choice ($P = 0.07$) in the Lactipro group. Steers dosed with Lactipro and placed directly onto a finishing diet had similar carcass traits to steers gradually adapted to a finishing diet. In addition, placing steers directly onto a finishing diet did not increase the occurrence or severity of liver abscesses.

Exp. 2 apparent total tract digestibility

Results for DMI, fecal output, and apparent total tract digestibilities during the step-up period are summarized in Tables 3-7 and 3-8. Dry matter intake was greater for Control steers than for Lactipro steers during the 24-d collection ($P < 0.01$). There was a period effect on DMI, with intake increasing for both treatments over the 24-d collection. Dry matter fecal output was lower ($P < 0.01$) for Lactipro steers compared to Control steers during the 24-d collection. Fecal output (DM) increased over time for both Control and Lactipro steers ($P < 0.01$). There was no treatment effect ($P = 0.11$) for apparent total tract DM digestibility, however there was a period effect ($P < 0.01$) with apparent total tract digestibility increasing over the 24-d collection. There was a treatment × period interaction ($P = 0.02$) and a period effect (P < 0.01) for apparent total tract CP digestibility. Apparent total tract digestibility of CP was lower for Lactipro steers during d 1 to 6 (P =0.05) and greater during d 7 to 12 ($P < 0.01$) compared to Control steers. During d 13 to 18 and d 19 to 24 apparent total tract CP digestibility was not different ($P \geq 0.12$) between treatment groups. Apparent total tract digestibility of CP was greater ($P = 0.05$) for Lactipro steers compared to Control steers during the 24-d collection. There was a treatment × period interaction ($P < 0.01$) and a period effect ($P < 0.01$) for apparent total tract NDF digestibility. Apparent total tract digestibility of NDF during d 1 to 6 was greatest ($P < 0.01$) for Control steers and was actually negative for Lactipro steers. There were no differences ($P \geq$ 0.30) in apparent total tract NDF digestibility between treatment groups during any of the other step-up periods. Control steers had a greater ($P < 0.01$) apparent total tract NDF digestibility than Lactipro steers during the 24-d collection. Apparent total tract starch digestibility was not different ($P \geq 0.26$) between treatments for any of the step-up periods or the 24-d collection. There was a treatment × period interaction ($P < 0.01$) and a period effect ($P < 0.01$) for phosphorous digestibility. Phosphorous digestibility tended to be greater ($P = 0.06$) during d 1 to 6 for the Control steers, but greater ($P < 0.01$) during d 7 to 12 for Lactipro steers. There were no differences ($P \geq 0.24$) during d 13 to 18 or d 19 to 24 for phosphorus digestibility. Phosphorous digestibility tended ($P = 0.07$) to be greater for Lactipro steers compared to Control steers during the 24-d collection.

During the digestibility study, DMI was lower for Lactipro steers, which further suggests that the tendency for lower DMI in the finishing trial can be largely attributed to the differences during the diet transition phase. Negative apparent total tract digestibility for NDF in Lactipro steers during the first 6 d suggests that portions of the roughage offered on arrival may have remained in the GI tract for an extended period of time. Although we did not measure passage rate it is possible that the depressed DMI of steers given Lactipro may have been influenced by depressed fiber digestion and decreased passage rate. If substantial quantities of residual hay were present, due to hay being fed the previous day, intake may have been limited as a result of gut fill. Forage passage rate is negatively associated with level of concentrate in the diet. Passage rate of forages is slower when a 90% concentrate diet is fed compared to when a 60% or 30% concentrate diet is fed (13% and 28% respectively; Poore et al., 1990). Owens and Goetsch, (1988) suggested that during adaptation from high-forage to high-concentrate diets fiber may accumulate in the rumen as a result of reduced rate of passage and digestion. Therefore, gut fill may have limited intake during first few days on feed. Our bunk management standard operating procedure limits daily increases in feed deliveries to no more than of 0.45 kg (dry basis) per animal. As long as the feed deliveries of both Lactipro and Control steers were increased at the maximum rate, the difference in feed deliveries between the treatments would remain constant. Daily DM feed deliveries support this theory as once the Control steers intake plateaued, Lactipro steers intake reached that of Control steers and remained similar for the remainder of the study. Lower fecal outputs during the step-up period for steers placed directly onto finishing diets were driven by lower DMI. Although DM digestibility was not significantly different during the step-up period it was numerically higher for steers placed directly onto finishing diets, which would also decrease fecal output. Elevated environmental concerns have made feedlot manure management increasingly critical. Decreasing fecal output would be beneficial to a feedlot due to a reduction in labor required for removal of the manure. Additionally, the environmental impact of the feedlot would be reduced. Digestibility of CP was higher for Lactipro steers which may be a result of the proteolytic activity of *Megasphaera elsdenii* (Scheifinger et al., 1976). Runoff of nitrogen and phosphorus along with volatilization of nitrogen from the pen surface or in the field following application has become an environmental concern for cattle operations. The increased feeding of by-products feeds as an energy sources has resulted in overfeeding of nitrogen and phosphorus therefore increasing the excretion of these two nutrients (Luebbe et al., 2012). Utilizing Lactipro to eliminate the step-up period provides a means to reduce environmental impact through reduced fecal output and improved CP and phosphorous digestibility. Feeding high-roughage diets prior to dosing with Lactipro and placing cattle onto high-concentrate diets may reduce intakes due to gut fill.

Implications

Despite reduced DMI during the step-up period steers can be placed directly onto finishing diets eliminating the need for mixing multiple step-up diets, maintain comparable performance and carcass characteristics to steers placed on a traditional step-up program. Additionally, the amount of roughage required during the finishing period can be reduced helping alleviate some of the burden associated with procuring and handling roughages.

Literature Cited

AOAC. 1995. Official Methods of Analysis. 16th ed. Assoc. Off. Anal. Chem., Arlington, VA.

Allison, M. J., J. A. Bucklin, and R. W. Dougherty. 1964. Ruminal changes after overfeeding with wheat and the effect of intraruminal inoculation on adaptation to a ration containing wheat. J. Anim. Sci. 23:1164-1171.

Bowling, R. A., J. K. Riggs, G. C. Smith, Z. L. Carpenter, R. L. Reddish, and O. D. Butler. 1978. Production, carcass and palatability characteristics of steers produced by different management systems. J. Anim. Sci. 46:33-340.

Brent, B. E. 1976. Relationship of acidosis and other feedlot ailments. J. Anim. Sci. 43:930-935.

Brink, D. R., S. R. Lowry, R. A. Stock, and J. C. Parrott. 1990. Severity of liver abscesses and efficiency of feed utilization of feedlot cattle. J. Anim. Sci. 68:1201-1207.

Britton R. A. and R. A. Stock 1986. Acidosis, rate of starch digestion and intake. In: F. N. Owens (ed.) Symposium Proceedings: Feed Intake by Beef Cattle. Publ. MP 121. P 125. Oklahoma State Univ., Stillwater.

Brown, M. S., C. H. Ponce, and R. Pulikanti. 2006. Adaptation of beef cattle to high-concentrate diets: Performance and ruminal metabolism. J. Anim. Sci. 84:E25-E33.

Fiske, C. H. and Y. Subbarow. 1925. The calorimetric determination of phosphorus. J. Biol. Chem. 66:375.

Gochman, N., and J. M. Schmitz. 1972. Application of new peroxide indicator reaction to specific automated determination of glucose with glucose oxidase. Clin. Chem. 18:943-950.

Henning, P. H., C. H., Horn, K.-J. Leeuw, H. H. Meissner, and F. M. Hagg. 2010. Effect of ruminal administration of the lactate-utilizing strain *Megasphaera elsdenii* (ME) NCIMB 41125 on abrupt or gradual transition from forage to concentrate diets. Anim. Feed. Sci. Technol. 157:20-29.

Herrera-Saldana, R., and J. T. Huber. 1989. Influence of varying protein and starch degradabilities on performance of lactating cows. J. Dairy Sci. 72:1477-1483.

Klieve, A. V., D. Hennessy, D. Ouwerkerk, R. J. Forster, R. I. Mackie, and G. T. Attwood. 2003. Establishing populations of *Megasphaera elsdenii* YE 34 and *Butyrivibrio fibrisolvens* YE 44 in the rumen of cattle fed high grain diets. J. Appl. Microbiol. 95:621-630.

Kung, L. Jr and A. O. Hession. 1995. Preventing *in vitro* lactate accumulation in ruminal fermentations by inoculation with *Megasphaera elsdenii*. J. Anim. Sci. 73:250-256.

Luebbe, M. K., G. E. Erickson, T. J. Klopfenstein, and M. A. Greenquist. 2012. Nutrient mass balance and performance of feedlot cattle fed corn wet distillers grains plus solubles. J. Anim. Sci. 90:296-306.

McDaniel, M. R. 2009. The effects of dosing feedlot cattle with *Megasphaera elsdenii* strain NCIMB 41125 prior to the introduction of a grain-rich diet. MS Thesis. Kansas State Univ., Manhattan.

Meissner, H. H., P. H. Henning, C. H. Horn, K-J. Leeuw, F. M. Hagg, and G. Fouché. 2010. Ruminal acidosis: A review with detailed reference to the controlling agent *Megasphaera elsdenii* NCIMB 41125. S. Afr. J. Anim. Sci. 40:79-100.

Nagaraja, T. G. and K. F. Lechtenberg. 2007. Acidosis in feedlot cattle. Vet. Clin. Food Anim. 23:333-350.

Nagaraja, T. G. and M. M. Chengappa. 1998. Liver abscesses in feedlot cattle: a review. J. Anim. Sci. 76:287-298.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1998. Acidosis in cattle: a review. J. Aim. Sci. 76:275-286.

Owens, F. N. and A. L. Goetsch. 1988. Ruminal Fermentation. In: The Ruminant Animal: Digestive Physiology and Nutrition. Waverland Press, Inc. Englewood Cliffs, NJ. p. 145-171.

Poore, M. H., J. A. Moore, and R. S. Swingle. 1990. Differential passage rates and digestion of neutral detergent fiber from grain and forages in 30, 60, and 90% concentrate diets fed to steers. J. Anim. Sci. 68:2965-2973.

RAGFAR. 2007. Ruminal acidosis – understandings, prevention and treatment. A review of veterinarians and nutritional professionals. Australian Veterinary Association: Qld.

Robinson, J. A., W. J. Smolenski, R. C. Greening, M. L. Ogilvie, R. L. Bell, K. Barsuhn, and J. P. Peters. 1992. Prevention of acute acidosis and enhancement of feed intake in the bovine by *Megasphaera elsdenii* 407A. J. Anim. Sci. 70 (Supp. 1):310 (Abstr).

Scheifinger, C., N. Russell, and W. Chalupa. 1976. Degradation of amino acids by pure cultures of rumen bacteria. J. Anim. Sci. 43:821-827.

Uhart, B. A. and F. D. Carroll. 1967. Acidosis in beef steers. J. Anim. Sci. 26:1195-1198.

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Table 3-1. Step-up regimes for treatment groups (Exp. 1 and Exp. 2).

Days on feed	Control	Lactipro
0-6	Step 1	Finisher
7-12	Step 2	Finisher
13-18	Step 3	Finisher
19-115	Finisher	Finisher

Table 3-2. Composition of experimental diets on a 100% dry matter basis (Exp. 1 and Exp. 2).

	Step-up Diets			
Ingredient, % of DM	Step 1	Step 2	Step 3	Finisher
Steam-flaked corn	30.2	40.2	50.2	60.2
Wet corn gluten feed	25.0	25.0	25.0	25.0
Corn silage	40.0	30.0	20.0	10.0
Supplement[1]	2.64	2.64	2.64	2.64
Feed additive premix[2]	2.16	2.16	2.16	2.16
Nutrient composition, analyzed, %				
DM	53.9	58.0	62.7	68.3
CP	13.5	13.7	13.8	14.0
NDF	25.0	22.4	19.9	17.4
Crude fat	3.3	3.4	3.6	3.7
Calcium	0.77	0.75	0.72	0.70
Phosphorus	0.44	0.45	0.45	0.45
Potassium	0.92	0.85	0.77	0.70

[1]Formulated to provide 0.3% salt, 0.1 mg/kg Co; 10 mg/kg Cu; 0.6 mg/kg I; 60 mg/kg Mn; 0.25 mg/kg Se; 60 mg/kg Zn; 2,200 IU/kg vitamin A; and 20 IU/kg vitamin E in the total diet on a DM basis.

[2]Formulated to provide 300 mg monensin and 90 mg tylosin (Elanco Animal Health, Indianapolis, IN) per steer daily.

Table 3-3. Feedlot performance of steers orally dosed with *M. elsdenii* at initial processing and placed onto a finishing diet.

	Treatment			
Item	Control	Lactipro	SEM	*P*-value
No. of cattle	221	222	--	--
Days on feed	115	115	--	--
Initial BW, kg	402	399	2.44	0.12
Final BW, kg[1]	663	657	5.31	0.21
DMI, kg/d	12.8	12.6	0.12	0.07
DM silage intake, kg/steer				
d 0 to 19	43.2	13.4	0.37	< 0.01
d 0 to 115	176.3	146.2	1.34	< 0.01
ADG, kg/d	2.26	2.25	0.034	0.65
G:F, kg/kg	0.1760	0.1785	0.0016	0.14

[1]Final BW shrunk (4%)

Table 3-4. Carcass characteristics and liver abscess scores of steers orally dosed with *M. elsdenii* at initial processing and placed onto a finishing diet.

	Treatment			
Item	Control	Lactipro	SEM	*P*-value
HCW, kg	402	400	3.2	0.23
Dressed yield, %	60.7	60.7	0.66	0.61
LM area, cm^2	90.5	90.1	0.10	0.59
KPH, %	2.29	2.29	0.050	0.92
Subcutaneous fat thickness, 12^{th}-rib, cm	1.36	1.32	0.024	0.28
Liver abscess, %	11.8	10.8	2.14	0.75
Abscess severity, %[1]				
A-	7.2	5.0	1.61	0.32
A	2.3	4.5	1.30	0.19
A+	2.3	1.4	0.91	0.47

[1]Liver abscess scores of A-, A, and A+ represent slight, moderate, or severe abscesses, respectively.

Table 3-5. USDA yield grades of steers orally dosed with Lactipro (*M. elsdenii*) at initial processing and placed onto a finishing diet.

	Treatment			
Item	Control	Lactipro	SEM	*P*-value
USDA yield grade	2.9	2.9	0.05	0.82
YG 1, %	2.3	0.5	0.78	0.10
YG 2, %	20.4	26.1	2.87	0.15
YG 3, %	61.3	54.7	3.71	0.16
YG 4, %	15.4	17.2	3.24	0.60
YG 5, %	0.5	1.4	0.64	0.32

Table 3-6. USDA quality grades and marbling scores of steers orally dosed with Lactipro (*M. elsdenii*) at initial processing and placed onto a finishing diet.

	Treatment			
Item	Control	Lactipro	SEM	*P*-value
Marbling[1]	457	461	4.51	0.55
Prime, %	1.4	0.5	0.64	0.31
Premium choice, %	24.4	28.4	2.97	0.35
Choice, %	80.1	86.5	2.50	0.07
Select, %	18.6	12.2	2.42	0.06
No roll, %[2]	0.0	0.9	0.52	0.15
B-maturity, %	1.8	0.4	0.72	0.18

[1]Marbling score determined by USDA graders. Values ranging from 400 to 499 represent a Small degree of marbling.
[2]Low quality carcasses that were not assigned a USDA quality grade

Table 3-7. Apparent total tract digestibility of during the first 24 d on feed for steers dosed with Lactipro (*M. elsdenii*) at processing and placed directly onto finishing diets.

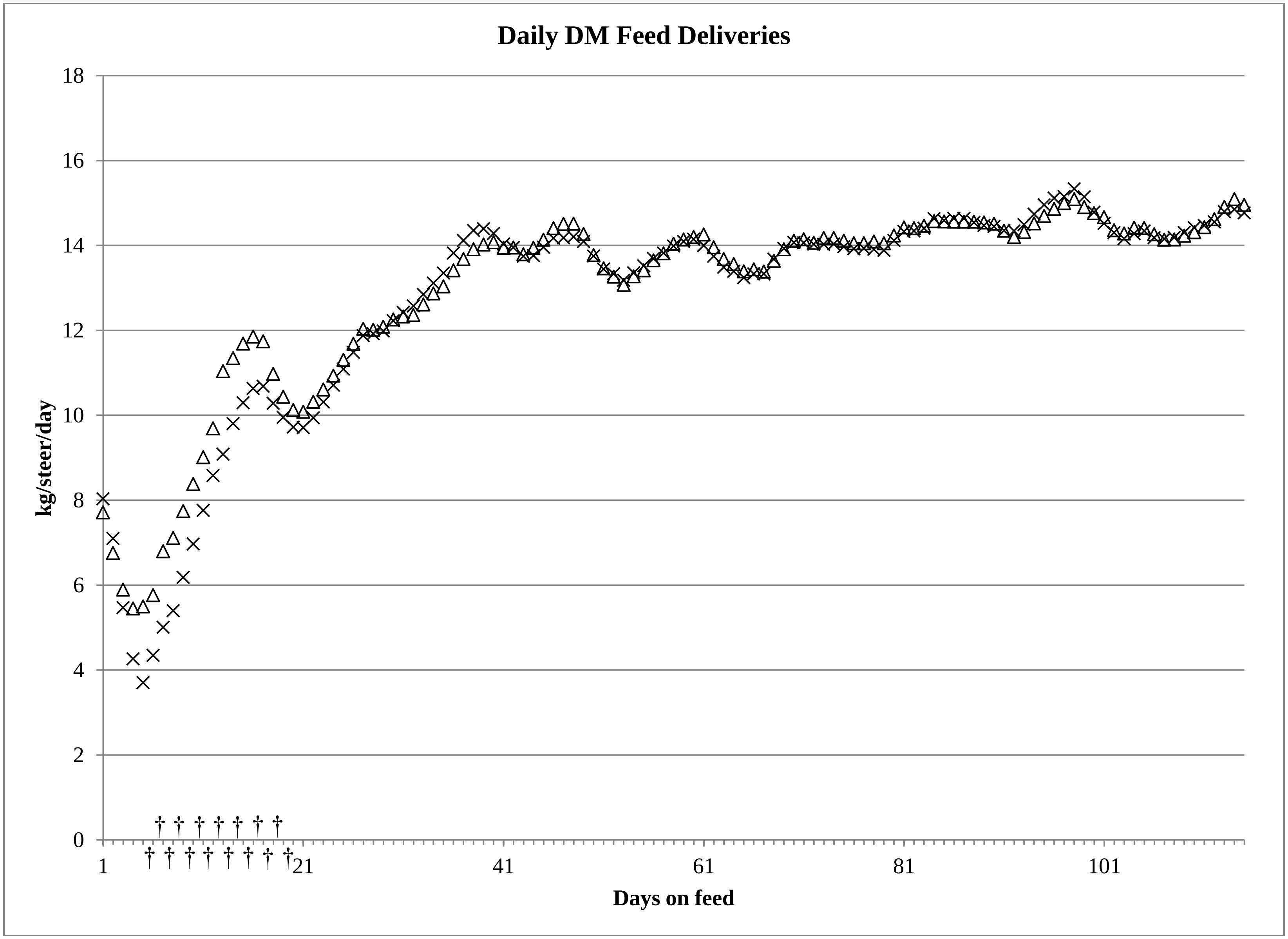
				P-value		
Item	Control	Lactipro	SEM	Treatment	Period[1]	Treatment × period
DMI, kg	8.9	7.7	0.15	< 0.01	< 0.01	0.42
Fecal output, kg	2.3	1.7	0.06	< 0.01	< 0.01	0.27
Apparent total tract digestibility, %						
DM	72.9	74.5	0.73	0.11	< 0.01	< 0.01
CP	70.0	71.8	0.69	0.05	< 0.01	0.02
NDF	45.8	35.8	2.81	< 0.01	< 0.01	< 0.01
Starch	99.9	99.8	0.04	0.30	0.84	0.88
P	32.6	40.2	2.79	0.07	< 0.01	< 0.01

[1]Periods were 6-d each corresponding to each adaptation diet fed to the Control steers and 6 d of feeding the finishing diet

Table 3-8. Apparent total tract digestibility by period during the first 24 d on feed of steers dosed with Lactipro (M. elsdenii) at initial processing and placed onto a finishing diet.

Item	Control	Lactipro	SEM	*P*-value
Days 1-6				
DMI, kg	5.2	3.7	0.30	< 0.01
Fecal output, kg/d	1.9	1.5	0.10	< 0.01
Digestibility, %				
DM	63.0	56.6	1.41	0.11
CP	65.8	62.9	1.29	0.05
NDF	28.0	-24.5	4.92	< 0.01
Starch	99.9	99.8	0.08	0.31
P	30.3	14.7	5.58	0.06
Days 7-12				
DMI, kg	8.2	6.5	0.30	< 0.01
Fecal output, kg/d	1.9	1.2	0.10	< 0.01
Digestibility, %				
DM	76.8	81.9	1.41	0.01
CP	75.0	80.4	1.29	< 0.01
NDF	56.3	56.4	4.92	0.99
Starch	99.8	99.8	0.08	0.61
P	27.6	54.7	5.58	< 0.01
Days 13-18				
DMI, kg	10.4	9.7	0.30	0.12
Fecal output, kg/d	2.7	2.0	0.10	< 0.01
Digestibility, %				
DM	74.3	79.6	1.41	0.01
CP	70.0	72.8	1.29	0.12
NDF	49.2	56.2	4.92	0.30
Starch	99.9	99.8	0.08	0.26
P	36.9	46.4	5.58	0.24
Days 19-24				
DMI, kg	12.0	10.7	0.30	< 0.01
Fecal output, kg/d	2.7	2.2	0.10	< 0.01
Digestibility, %				
DM	77.6	80.0	1.41	0.25
CP	69.2	71.3	1.29	0.24
NDF	49.8	55.3	4.92	0.41
Starch	99.8	99.8	0.08	0.99
P	35.8	44.9	5.58	0.26

Figure 3-1. Daily DM feed deliveries during the 115 d finisher period for steers dosed with Lactipro (*M. elsdenii*) and placed directly onto a finishing diet (Δ Control, $\times$ Lactipro; SEM = 0.22; treatment $P < 0.01$; day $P < 0.01$; treatment $\times$ day $P < 0.01$). Days DM feed deliveries differ (†, $P < 0.05$)


Daily DM Feed Deliveries
kg/steer/day
18
16
14
12
10
8
6
4
2
0
1
21
41
61
81
101
Days on feed

Chapter 4 : **Dosing high-risk calves at processing with *Megasphaera elsdenii* to reduce the number of calves treated for BRD**[1]

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Abstract

Two experiments were conducted to determine the effect of a 100-mL oral dose of the *Megasphaera elsdenii*-containing product, Lactipro®[e], at initial processing, on the health and performance of high-risk calves during the receiving period. In Exp. 1, 1294 crossbred steers (BW = 262 ± 1.3 lb) were received from Mexico over a 13-d period in November and December of 2011. Steers were provided hay upon arrival and processed approximately 24 h later. At processing steers were assigned to a CON group (no *M. elsdenii*) or a ME treatment group (100-mL oral dose of *M. elsdenii*) based on alternating order through the chute. Steers were housed in 10 concrete-surfaced pens with 15 or 16 steers/pen or 28 dirt-surfaced pens with 39 to 42 steers/pen. All steers were fed a 55% concentrate receiving diet *ad libitum*. Steers were observed daily for signs of undifferentiated bovine respiratory disease (UBRD). Steers determined to be sick with UBRD were taken to the processing area and given antibiotic therapy (1^{st} antibiotic therapy, tilmicosin; 2^{nd} antibiotic therapy, enrofloxacin; 3^{rd} antibiotic therapy, long-acting oxytetracycline). There were no differences observed in DMI, ADG, feed efficiency, overall morbidity, or mortality ($P \geq 0.53$). Incidence of 1^{st}- and 3^{rd}-time antibiotic therapy were not different between CON and ME steers ($P \geq 0.16$); however, ME steers tended to have a lower incidence of 2^{nd}-time antibiotic therapies ($P = 0.06$). In Exp. 2, crossbred calves (504 bulls, 141 steers; BW = 443 ± 10.8 lb) were received from Texas over a 2-wk period in January, 2012. Bulls were castrated at processing and treatments and allocation to treatment were the same as Exp. 1. Calves were housed in 24 dirt-surfaced pens with 25 to 30 calves/pen, fed a 55% concentrate receiving diet, observed daily for clinical signs of respiratory disease and treated for UBRD as described for Exp. 1. Calves dosed with *M. elsdenii* had greater DMI, ADG, and feed efficiency ($P \leq 0.05$) than CON calves. Instances of 1^{st}- and 2^{nd}-time therapeutic

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treatments for UBRD were 31% and 33% less for calves given *M. elsdenii* compared to the control group ($P < 0.05$). Third-time antibiotic therapy for UBRD and mortalities were not different between treatments ($P > 0.01$), but UBRD therapeutic treatment cost per calf was decreased by 13% ($P < 0.05$) for calves in the ME treatment. Dosing calves with Lactipro at processing was effective as a method for improving performance and decreasing clinical signs of UBRD.

Bovine respiratory disease, high-risk calves, Lactipro

Introduction

The most common causes of mortalities in cattle and calves are respiratory disease and digestive disorders, accounting for 28 and 13% of mortalities, respectively.[19] Treatment cost, reduced performance, and death loss are incurred when cattle experience bovine respiratory disease (BRD).[5] Lightweight calves coming into the feedlot are at high risk of BRD due to the stress associated with weaning, transportation, feed and water deprivation, commingling, castration, and other factors.[18] Calves often are naïve to feed bunks and the feedstuffs that are presented to them. This, combined with the stress of transportation, results in reduced intake, potentially compromising immune function and adding to the risk of BRD.[4] Cattle may also succumb to acidosis when concentrates are introduced into their diet, further reducing intake and performance.[13] Moreover, symptoms of BRD, which include inappetance, increased respiration, lethargy, depression, loss of muscle tone, and nasal and ocular discharge, are not readily distinguished from clinical symptoms of acute acidosis, leading to frequent misdiagnosis.[12] Therapies designed to address BRD would not be expected to have significant impact on animals afflicted with acidosis, inevitably leading to the perception that antibiotic treatments have only limited efficacy. Acidosis is most logically dealt with through preventive measures. *Megasphaera elsdenii* is capable of establishing a viable population when administered to cattle prior to feeding concentrates, preventing ruminal lactate accumulation and depression of ruminal pH.[8, 10, 11] We hypothesized that the administration of Lactipro®,[e] a source of the lactate-utilizing bacterium *Megasphaera elsdenii*, at initial processing would decrease incidence of acidosis in newly arrived feedlot calves, resulting in fewer calves exhibiting clinical symptoms similar to those associated with BRD, thus decreasing the number of animals inappropriately diagnosed and treated for BRD. Our objective was to determine if dosing cattle with *M. elsdenii* at processing would decrease morbidity and mortality of lightweight calves received into the feedlot.

Materials and Methods

Exp. 1

Care and handling of the animals used in this study were conducted under the approval of the Kansas State University Institutional Animal Care and Use Committee (protocol No. 2914). Crossbred steers (n = 1294, BW = 262 ± 1.3 lb) were received from Mexico from November 24, 2011 through December 6, 2011. Steers received *ad libitum* brome hay on arrival and were processed through the chute approximately 24 h after arrival. At processing, steers were vaccinated against common viral[a] and clostridial[b] diseases, treated for internal and external parasites[c], weighed, given a uniquely numbered ear tag, and given tulathromycin[d] (1.1 mg/lb) metaphylactically. Steers were blocked by arrival date and randomly assigned to one of two treatments based on order through the chute at processing, resulting in 10 pens with 15 or 16 steers/pen and 28 pens with 39- to -42 steers/pen. The 10 pens were concrete-surfaced (595 ft^2), equipped with automatic water fountains shared by adjacent pens, and provided 14.1 linear ft of bunk space. The 28 pens were dirt-surfaced pens (4650 ft^2), equipped with automatic water fountains shared by adjacent pens, and provided 30.8 linear ft of bunk space. Treatments were a control group which did not receive *M. elsdenii* at processing (CON) and a group that received a 100-mL oral dose of *M. elsdenii* (Lactipro®)[e] at processing (ME).

Steers were fed a common receiving diet (Table 4-1) once daily. The diet was fed to achieve *ad libitum* intake. Several incidences of polioencephalomalacia were initially observed; therefore the amount of wet corn gluten feed in the diet was decreased after d 33. (Table 4-1).

This lower level of wet corn gluten feed was fed for the remainder of the feeding period and no additional cases of polioencephalomalacia occurred.

Calves were observed daily (pen riders were not blinded to treatment) and animals exhibiting signs of illness were removed from their pen and taken to the treatment area for further evaluation and treatment. Illness signs included lethargy, depression, diarrhea, nasal and ocular discharge, inappetance, or increased respiration. At the chute rectal temperature and BW were recorded. If animals were suspected of having undifferentiated bovine respiratory disease (UBRD) they were given tilmicosin[f] for 1st-time antibiotic therapy, enrofloxacin[g] for 2nd-time antibiotic therapy, and long-lasting oxytetracycline[h] for 3rd-time antibiotic therapy. Animals suspected of other illnesses were treated according to Kansas State University Beef Cattle Research Center standardized operating procedures.

Exp. 2

Care and handling of animals used in this study were conducted under the approval of the Kansas State University Institutional Animal Care and Use Committee (protocol No. 2914). Crossbred calves (504 bulls, 141 steers; BW = 443 ± 10.8 lb) were received from Texas over a 2-wk period in January (2 loads per day; on the 14th, 19th, and 26th). Calves were given brome hay on arrival, and within 24 h were weighed, vaccinated,[a,b] dewormed[c], castrated[i], treated with tilmicosin[f] (4.5 mg/lb), and identified with uniquely numbered ear tags. Calves were blocked by arrival date and randomly assigned to one of two treatments based on order through the processing chute. Bull was not used as a sorting criteria (CON = 250 bulls, ME = 254 bulls). Treatments were a control group which did not receive *M. elsdenii* at processing (CON) and a group that received a 100-mL oral dose of *M. elsdenii* (Lactipro®)[e] at processing (ME). Animals were blocked by arrival date and randomly assigned to 24 pens with 25 to 30 calves/pen. Calves were housed in dirt-surfaced pens (4650 ft^2) equipped with automatic water fountains shared by adjacent pens and 30.8 ft of bunk space. All calves received a common diet throughout the 85-d receiving period (Table 4-1). Calves were monitored daily as in Exp. 1 and therapeutic treatment protocols were the same.

Statistical analysis

Data were analyzed for both studies using the MIXED procedure of SAS 9.1 (SAS Institute Inc., Cary, NC). Pen was the experimental unit, treatment was the fixed effect, and strata was the random variable.

Results and Discussion

Exp. 1 health

Calves in Exp. 1 were light weight, commingled, and transported long distances, all of which have been identified as factors predisposing cattle to BRD.[18] Health data is summarized in Table 4-2. Overall morbidity was 4.57% and was not different (P = 0.68) between treatments. Rectal temperature taken when therapeutic treatment for UBRD was administered did not differ between treatment groups (P = 0.35, Fig. 4-1). The percentage of steers given a 1st antibiotic therapy for UBRD was similar (P = 0.34) between treatments, but dosing calves with *M. elsdenii* tended (P = 0.06) to decrease the number of calves requiring a 2nd antibiotic therapy. Incidence of 3rd-time antibiotic therapy was low and not different (P = 0.16) between treatments. Overall morbidity and incidence of UBRD were relatively low in our study. Average incidence for BRD in United States feedlots was estimated to be 14.4% in 1999 and 17% over a 15-yr period from 1987-2001.[14,16] Based on the low incidence of UBRD in our study and the limited impact of *M. elsdenii* it can be assumed that neither BRD nor acidosis were major problems in these calves.

There was a trend for fewer cattle to require a follow-up antibiotic therapy when calves were given *M. elsdenii* at processing. Morbid calves are seen at the bunk less frequently than healthy calves, and as cattle regain their appetites they may be prone to overeating and thus at the risk of acidosis.[17] If calves were to experience acidosis at this stage their appearance would be similar to that of a calf afflicted with BRD.[12] Alternatively, if calves experience acidosis, appetite is depressed; this can suppress immune function and predispose animals to a relapse of BRD.[2] The trend for reduced 2nd-time antibiotic therapy in ME steers may have been a result of preventing acidosis when appetite began to increase. There were no differences ($P \geq 0.18$) between CON and ME steers in the number of calves treated for polioencephalomalacia, foot rot, lameness, pinkeye, or coccidiosis. Mortality was not different ($P = 0.53$) between treatments during the receiving period.

Exp. 1 performance

Dosing steers with *M. elsdenii* at processing resulted in similar DMI ($P = 0.88$), ADG ($P = 0.84$), and feed efficiency ($P = 0.78$) during the receiving period compared to CON steers (Table 4-3). Daily dry matter feed deliveries are summarized in Fig. 4-2 and were not different between CON and ME steers ($P = 0.89$), but there was a significant day effect with feed deliveries increasing over time for both groups ($P < 0.01$). The lack of significant differences in performance between the two treatments is not surprising, as the differences in morbidity were minimal. Other probiotic products have been shown to increase performance during the receiving period.[9] The mechanisms by which this occurs is largely unknown, but it has been suggested that probiotics may improve digestion, absorption, or may have a competitive advantage over pathogenic organisms, therefore decreasing pathogen prevalence.[3] Many of the probiotics evaluated by Duff and Galyean were believed to alter the lower GI tract function, whereas *M. elsdenii* impacts the rumen by preventing lactic acid accumulation.[3,10] It does not appear that acidosis was a major problem in the current study, which may have limited the efficacy of *M. elsdenii*.

Exp. 2 health

The calves utilized in Exp 2 also were light-weight, commingled, and transported long distances. In addition, 78% of the calves were castrated at processing, which is known to increase the risk of BRD.[18] Morbidity and mortalities during the receiving period are summarized in Table 4-4. Incidence of 1st-time antibiotic therapy for UBRD was reduced by 31% (P = 0.02) in calves given *M. elsdenii* compared to the CON calves. Dosing steers with *M. elsdenii* at processing also decreased the number of calves that required a 2nd antibiotic therapy by 34% (P = 0.03). The number of animals requiring a 3rd antibiotic treatment for UBRD did not differ between CON and ME groups (P = 0.36). Rectal temperatures taken when therapeutic treatment for UBRD was administered were not different between CON and ME groups (*P* = 0.16, Fig. 4-3). Differences in the effect of *M. elsdenii* on health between Exp. 1 and Exp. 2 are likely related to the difference in overall morbidity between the two groups of cattle (4.6% in Exp. 1 and 32% in Exp. 2). Our hypothesis was that decreasing the occurrence of acidosis would result in fewer calves exhibiting clinical signs of UBRD, therefore decreasing the number of calves that are misdiagnosed and given antibiotic therapy. Rivera reviewed 6 trials evaluating the effect of roughage level on morbidity and performance of calves during the receiving period and found that increasing roughage decreased morbidity and performance.[15] Increasing dietary roughage and dosing with *M. elsdenii* decrease the risk of acidosis.[11] This supports the hypothesis that decreasing the incidence of acidosis may decrease the number of calves perceived as having UBRD. Hagg reported a 67% decrease in the morbidity of dairy calves dosed with *M. elsdenii* 14 d after birth during a time when calves are being introduced to grains.[7] Although the incidence of morbidity was decreased in our study, there was no difference in mortality (P = 0.50) between CON and ME calves. Medical costs were 13.4% lower ($P = 0.01$) in ME calves compared to CON calves. *Megasphaera elsdenii* effectively decreased the number of animals given antibiotic therapy for UBRD and subsequently reduced therapeutic treatment cost per calf.

Exp. 2 performance

Performance during the 64-d receiving period is summarized in Table 4-5. Dry matter intake was greater when *M. elsdenii* was administered at processing ($P = 0.01$) compared to the CON group. Daily dry matter feed deliveries were greater for the ME calves on d 19, 20, 21, 22, 41, and 42 compared to the Control calves ($P < 0.05$, Fig. 4-4). Low intakes can be a problem in light-weight, high-risk calves.[2] *Megasphaera elsdenii* improved intake during the receiving period, which may have contributed to the improved health status. Furthermore, ADG was greater ($P = 0.02$) for ME calves compared to CON calves. Dosing steers with *M. elsdenii* also resulted in a 15.5% improvement ($P = 0.05$) in feed efficiency. Because incidence of UBRD was greater in control calves it would be expected that performance would suffer. Calves treated for BRD have reduced ADG and gain efficiencies compared to their untreated counterparts.[5] Furthermore, the presence of lung lesions at the processing facility, which can result from BRD, is negatively correlated with performance.[1] *M. elsdenii* decreases the risk of acidosis by providing a population of lactate utilizing bacteria that prevent lactic acid accumulation.[8,10,11] Cattle experiencing acidosis typically have reduced DMI and poor performance[13]; therefore, the improvement in performance of ME steers may be related to a decrease in the incidence of acidosis and greater feed intake. Low DMI can result in nutrient deficiencies impairing the immune system.[2] The lower intakes of the control group may have contributed to the increased incidence of UBRD. Fewer calves exhibited clinical signs of UBRD when *M. elsdenii* was administered at processing, however there is no way of determining if the occurrence of UBRD was decreased or if a significant number of calves that were treated for UBRD in the CON group in fact were afflicted with acidosis. Although the exact mode of action is still unknown, administering *M. elsdenii* at processing to high-risk calves improved health and performance during the receiving period.

Implications

M. elsdenii improves health and performance of high-risk calves during the receiving period. Decreased therapeutic treatment for undifferentiated bovine respiratory disease decreased treatment cost per calf and reduced antibiotic usage. The efficacy of *M. elsdenii* for decreasing incidence of undifferentiated bovine respiratory disease may be diminished in low-risk calves which may not be as susceptible to acidosis and other related health issues during the receiving period.

Footnotes

[a]Bovi-Shield Gold® 5, Pfizer Animal Health, Exton, PA

[b]Ultrabac®-7, Pfizer Animal Health, Exton, PA

[c]Dectomax®, Pfizer Animal Health, Exton, PA

[d]Draxxin®, Pfizer Animal Health, Exton, PA

[e]Lactipro®, MS-Biotec, Inc., Wamego, KS

[f]Micotil®, Elanco Animal Health, Greenfield, IN

[g]Baytril®, Bayer Animal Health, Shawnee Mission, KS

[h]LA-200®, Pfizer Animal Health, Exton, PA

[i]Callicrate bander®, No-Bull Enterprises, LLC, St. Francis, KS

Literature Cited

1. Bryant LK, Perino L J, Griffin D, Doster AR, Wittum TE. Method for recording pulmonary lesions of beef calves at slaughter, and the association of lesions with average daily gain. *Bovine Pract* 1999;33:163-173.

2. Cole NA. Review of bovine respiratory disease: *Nutrition and disease—Schering-Plough Animal Health. R A Smith, ed.* Veterinary Learning Systems, Trenton, NJ, 1996;57-74.

3. Duff CG, Galyean ML. Recent advances in management of highly stressed, newly received feedlot cattle. *J Anim Sci* 2007;85:823-840.

4. Galyean ML, Perino LJ, Duff GC. Interaction of cattle health/immunity and nutrition. *J Anim Sci* 1999;77:1120-1134.

5. Gardner BA, Dolezal HG, Bryant LK, Owens FN, Smith RA. Health of finishing steers: effects on performance carcass traits, and meat tenderness. *J Anim Sci* 1999;77:3168-3175.

6. Gill D R, Smith RA, Ball RL. The effect of probiotic feeding on health and performance of newly-received stocker calves. *Oklahoma Agric Exp Stn* 1987;MP-119:202-204.

7. Hagg FM, Muya CM, Henning PH. The effect of *Megasphaera elsdenii* NCIMB 41125 (ME) on performance of pre-weaned dairy calves. *J Anim Sci* 2010;88: E-Suppl. 2 pg 420.

8. Klieve AV, Hennessy D, Ouwerkerk D, Forster RJ, Mackie RI, Attwood GT. Establishing populations of *Megasphaera elsdenii* YE 34 and *Butyrivibrio fibrisolvens* YE 44 in the rumen of cattle fed high grain diets. *J Appl Microbiol* 2003;95:621-630.

9. Krehbiel C R, Rust SR, Zhang G, Gilliland SE. Bacterial direct-fed microbials in ruminant diets: Performance response and mode of action. *J Anim Sci* 2003;81:E120-E132.

10. McDaniel MR. The effects of dosing feedlot cattle with *Megasphaera elsdenii* strain NCIMB 41125 prior to the introduction of a grain-rich diet. *MS Thesis. Kansas State Univ., Manhattan* 2009.

11. Meissner H H, Henning PH, Horn CH, Leeuw K-J, Hagg FM, Fouché G. Ruminal acidosis: A review with detailed reference to the controlling agent *Megasphaera elsdenii* NCIMB 41125. *S Afr J Anim Sci* 2010;40:79-100.

12. Montgomery, D. Bovine respiratory disease and diagnostic veterinary medicine (managing respiratory diseases in the herd). *Range Beef Cow Symposium*. Lincoln, NE. 2009. Paper 280.

13. Nagaraja TG, Lechtenberg KF. Acidosis in feedlot cattle. *Vet Clin Food Anim* 2007;23:333-350.

14. NAHMS. Feedlot '99 Part II: Baseline reference of feedlot health and health management. USDA, APHIS, National Animal Health Monitoring System. 2000. http://www.aphis.usda.gov/animal_health/nahms/feedlot/downloads/feedlot99/Feedlot99_dr_PartIII.pdf. Accessed October 3, 2012.

15. Rivera JD, Galyean ML, Nichols WT. Dietary roughage concentration and health of newly received cattle. *Prof Anim Sci* 2005;21:345-351.

16. Snowder GD, Van Velck LD, Cundiff LV, Bennett GL. Bovine respiratory disease in feedlot cattle: Environmental, genetic, and economic factors. *J Anim Sci* 2006;84:1999-2008.

17. Sowell BF, Branine ME, Bowman JG, Hubbert ME, Sherwood HE, Quimby W. Feeding and watering behavior of healthy and morbid steers in a commercial feedlot. *J Anim Sci* 1999;77:1105-1112.

18. Taylor JD, Fulton RW, Lehenbauer TW, Step DL, Confer AW. The epidemiology of bovine respiratory disease: What is the evidence for predisposing factors? *Can Vet J* 2010;51:1095-1102.

19. USDA. Cattle death loss. National Agriculture Statistics Service. 2011.

Table 4-1. Composition of experimental diets DM basis (Exp. 1 and Exp. 2).

Ingredient, % of DM	Original receiving diet[1]	Adjusted receiving diet[2, 3]
Steam-flaked corn	25.87	36.32
Wet corn gluten feed	25.87	15.00
Corn silage	45.00	45.00
Supplement[3]	1.82	2.24
Feed additive premix[4]	1.44	1.44
Nutrient analyses, %		
DM	51.92	53.41
CP	12.37	12.00
NDF	26.52	23.82
Calcium	0.70	0.70
Phosphorus	0.45	0.38
Potassium	0.89	0.81
Sulfur	0.23	0.19

[1]In Exp. 1 original diet was fed from d 1 to d 33.
[2]In Exp. 1 adjusted receiving diet was fed starting on d 34 to the end of the study due to several incidences of polioencephalomalacia.
[3]Adjusted receiving diet was fed throughout Exp. 2.
[3]Formulated to provide 0.30% salt, 0.1 ppm Co; 10.0 ppm Cu; 0.6 ppm I; 60 ppm Mn; 0.25 ppm Se; 60 ppm Zn; 1,000 IU/lb vitamin A; and 10 IU/lb vitamin E on a dry matter basis.
[4]Formulated to provide 200 mg monensin (Elanco Animal Health, Indianapolis, IN) per steer daily.

Table 4-2. Health of steers orally dosed with *M. elsdenii* at initial processing and placed onto a receiving diet (Exp. 1).

	Treatment			
% of total population	CON	ME	SEM	*P*-value
Total morbidity	4.81	4.34	1.40	0.68
Therapeutic treatment for UBRD[1]				
Rectal temperature, °F[2]	102.7	102.1	0.64	0.35
1st antibiotic therapy[3]	3.72	2.78	1.09	0.34
2nd antibiotic therapy[4]	0.92	0.16	0.30	0.06
3rd antibiotic therapy[5]	0.31	0.00	0.15	0.16
Polioencephalomalacia	0.31	0.46	0.29	0.66
Foot rot	0.46	0.15	0.22	0.32
Lameness[6]	0.15	0.62	0.24	0.18
Conjunctivitis	0.46	0.31	0.24	0.65
Coccidiosis	0.15	0.00	0.11	0.32
Mortality	0.62	0.92	0.35	0.53

[1]Undifferentiated bovine respiratory disease
[2]Rectal temperature taken when therapeutic treatment was administered
[3]First antibiotic therapy, tilmicosin
[4]Second antibiotic therapy, enrofloxacin
[5]Third antibiotic therapy, long-lasting oxytetracycline
[6]Lameness due to injury or infection

Figure 4-1. Rectal temperature of steers orally dosed with *M. elsdenii* at processing and placed onto a receiving diet.
Temperature was taken when therapeutic treatment for undifferentiated bovine respiratory disease was administered (SEM = 0.64). Δ CON, × ME (Exp. 1)

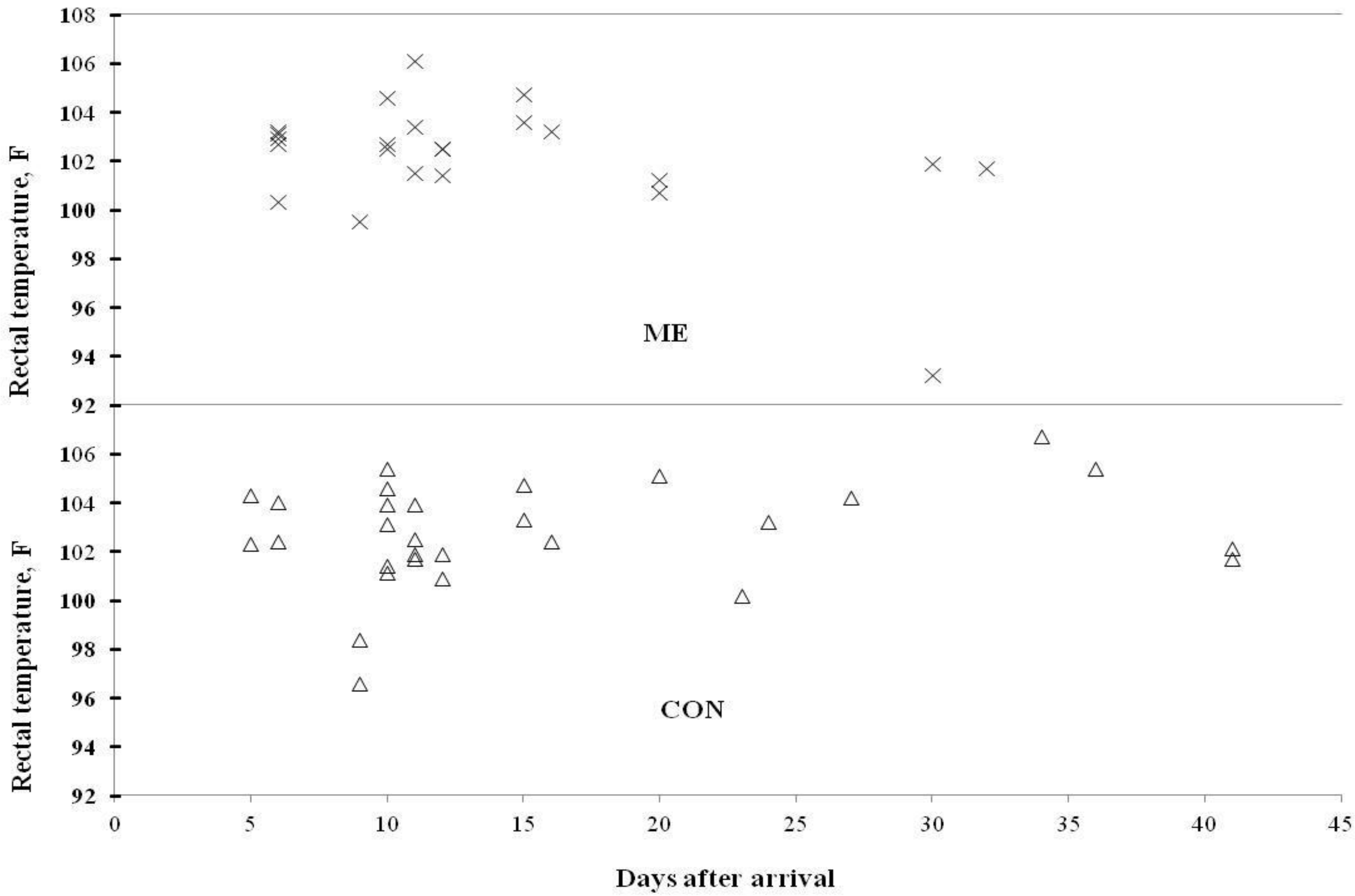

108
106
104
102
100
98
96
94
92
Rectal temperature, F
ME
106
104
102
100
98
96
94
92
Rectal temperature, F
CON
0
5
10
15
20
25
30
35
40
45
Days after arrival

Table 4-3. Performance of steers orally dosed with *M. elsdenii* at initial processing and placed onto a receiving diet (Exp. 1).

	Treatment			
Item	CON	ME	SEM	*P*-value
Initial BW, lb	265	262	1.3	0.70
Final BW, lb	366	366	3.2	0.98
DMI, lb/d	9.5	9.5	0.11	0.88
ADG, lb	2.5	2.5	0.04	0.84
F:G, lb:lb	3.87	3.86	0.116	0.90

Figure 4-2. Daily DM feed deliveries of steers orally dosed with *M. elsdenii* at initial processing and placed onto a receiving diet (Δ CON, × ME).
Treatment effect (P = 0.89), day effect (P < 0.01), treatment × day interaction (P = 1.0), and SEM = 0.22. (Exp. 1)

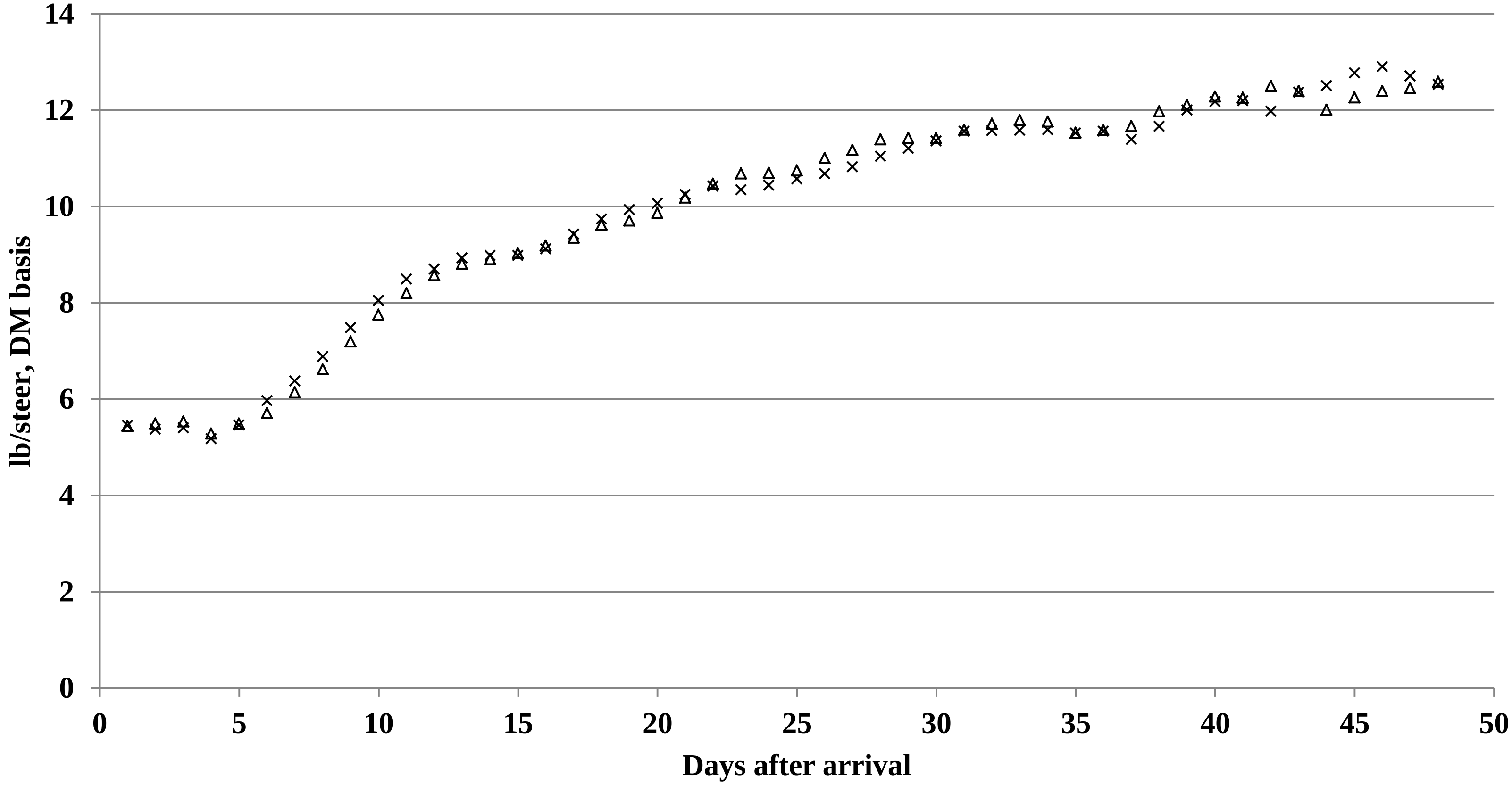
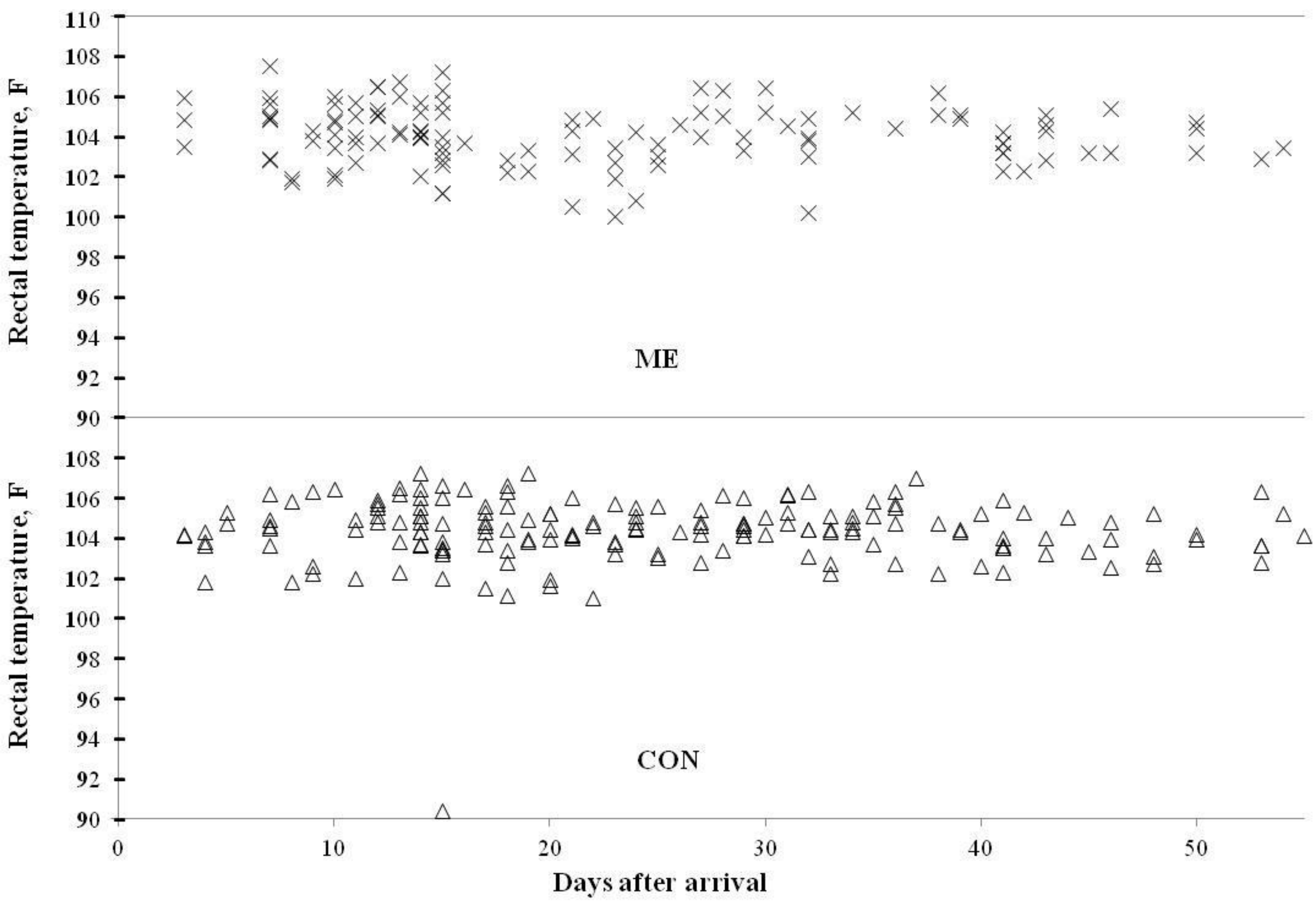

14
12
10
8
6
4
2
0
lb/steer, DM basis
0
5
10
15
20
25
30
35
40
45
50
Days after arrival

Table 4-4. Health of high-risk calves orally dosed with *M. elsdenii* at initial processing and placed onto a receiving diet (Exp. 2).

	Treatment			
% of total population	CON	ME	SEM	*P*-value
Total morbidity	37.7	26.4	4.81	0.02
Therapeutic treatment for UBRD[1]				
Rectal temperature, °F[2]	104.3	104.1	0.15	0.16
1st antibiotic therapy[3]	32.0	22.0	4.13	0.02
2nd antibiotic therapy[4]	17.4	11.5	2.09	0.03
3rd antibiotic therapy[5]	5.9	4.4	1.22	0.36
Conjunctivitis	0.64	1.60	0.52	0.19
Infectious lameness	0.31	0.29	0.30	0.96
Toe abscess	0.00	0.33	0.24	0.33
Injury[6]	1.87	0.32	0.64	0.11
Cocccidiosis	0.65	0.62	0.54	0.96
Free gas bloat	0.61	0.00	0.29	0.16
Other[7]	1.64	1.32	0.91	0.71
Mortality	4.9	3.8	1.13	0.50
Medical cost, $/calf[8]	19.70	17.06	0.98	0.01

[1]Undifferentiated bovine respiratory disease
[2]Rectal temperature was taken when therapeutic treatment was administered
[3]First antibiotic therapy, tilmicosin
[4]Second antibiotic therapy, enrofloxacin
[5]Third antibiotic therapy, long-lasting oxytetracycline
[6]Includes bullers and other injuries to the limbs resulting in lameness.
[7]Other includes treatment associated with infection of castration site
[8]Cost associated with treatment of undifferentiated respiratory disease

Figure 4-3. Rectal temperature of high-risk calves orally dosed with *M. elsdenii* at initial processing and placed onto a receiving diet.
Temperature was taken when therapeutic treatment for undifferentiated bovine respiratory disease was administered (SEM = 0.15). ∆ CON, × ME (Exp. 2)



110
108
106
104
102
100
98
96
94
92
90
Rectal temperature, F
ME
108
106
104
102
100
98
96
94
92
90
Rectal temperature, F
CON
0
10
20
30
40
50
Days after arrival

Figure 4-4. Daily DM feed deliveries of high-risk calves dosed with *M. elsdenii* at initial processing and placed onto a receiving diet (∆ CON × ME; Exp. 2).
Treatment effect $P < 0.01$, day effect $P < 0.01$, treatment × day interaction $P = 1.0$, and SEM = 0.41 († = $P < 0.10$; ‡ = $P < 0.05$).

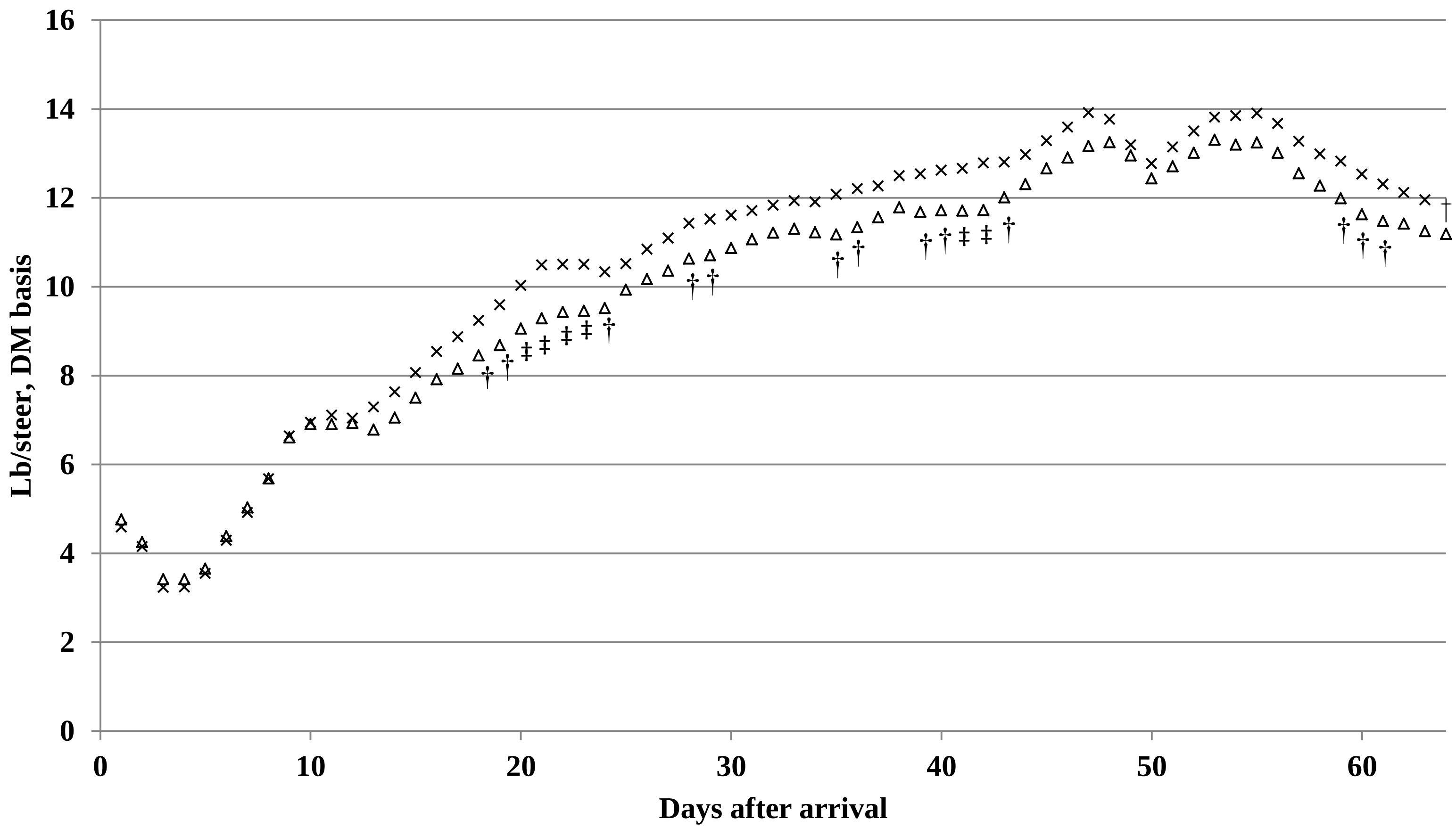

16
14
12
10
8
6
4
2
0
Lb/steer, DM basis
0
10
20
30
40
50
60
Days after arrival

Table 4-5. Performance of high-risk calves dosed with *M. elsdenii* at initial processing and placed onto a receiving diet (Exp. 2).

	Treatment			
Item	CON	ME	SEM	*P*-value
Initial weight, lb	441	445	10.8	0.23
Final weight, lb	558	580	9.3	< 0.01
DMI, lb/d	9.53	10.16	0.37	0.01
ADG, lb	1.42	1.76	0.15	0.02
F:G, lb:lb	6.80	5.75	0.598	< 0.05